RADIO and ELECTRONICS

ELECTRICITY — COMMUNICATIONS — SERVICE — SOUND

FEBRUARY 1, 1949 VOL. 3, NO. 11 1/10

ROLA MODEL 12^O^

This new model Rola loudspeaker incorporates in its design an entirely new magnetic circuit in which fullest use is made of the latest magnet alloys.

Due to this radically new magnet system and to a specially designed diaphragm, the model 12-O is capable of outstandingly fine performance. Its frequency range is greater than that covered by standard recordings or broadcast by the best of the broadcasting stations, and its transient response is such as to give full brilliance and tonal realism to its sound reproduction. This new 12-inch Rola loudspeaker is revolutionary in both design and performance.

Model 12-O will find special application in high-quality A.C. battery or vibrator-operated radio receivers and in sound systems which call for a highly efficient loudspeaker capable of wide-range reproduction.

REPLACEMENT INFORMATION

Model 12-0 can be used to replace the PM type Model 12/42 and the electro-dynamic Model K12. When Model 12-0 is used as a replacement for the K12, the field winding of the latter is replaced with a Type 14/60 choke and a series resistance of such value that, with the choke coil, the total D.C. resistance will equal that of the Model K12 field. In some cases, more capacity will be needed in the filter circuit.

TECHNICAL DATA

Power Handling Capacity ..	7 watts.
Fundamental Diaphragm Resonance	60-70 c.p.s. (F22 Cone).
Voice Coil Impedance ..	2 ohms at 400 c.p.s.
Transformer	Type "C" Isocore attached, or detached for chassis mounting.
Principal Dimensions ..	Overall diameter of cone housing .. .. .. $12\frac{1}{16}$" Diameter of baffle opening .. .. 11" Diameter of voice coil .. .. $1\frac{3}{4}$" Depth from pad-ring to rear, including transformer .. .. $5\frac{1}{4}$"
Mounting	Four slots spaced 90° on $11\frac{5}{8}$" pitch circle diameter. Dimensions of the slots, $\frac{1}{4}$" × $\frac{3}{4}$".
Finish	Diaphragm housing and transformer can silver lacquered, magnet black lacquered.
Weight	4 lb. 15 ozs. (including transformer).

Swan Electric Co. Ltd.

AUCKLAND · WELLINGTON · CHRISTCHURCH · DUNEDIN

RADIO and ELECTRONICS

Vol. 3, No. 11 — 1st February, 1949

Contents — Page

OUR COVER:

This month's cover picture shows the outward appearance of a small radar set developed for the Transport Department by the Department of Scientific and Industrial Research. Its purpose is to indicate, on a dial inside the car, the speed of passing vehicles. This it does with considerable accuracy, and should be useful not only for observing speeding motorists but for making statistical studies of the speed of traffic at particular road points.

CORRESPONDENCE

All correspondence, contributions, and enquiries referring to advertising space and rates should be addressed to:—

The Editor,
"Radio and Electronics,"
Box 22,
Government Buildings P.O.
WELLINGTON.

●

OFFICES AND LABORATORY:
Radio and Electronics (N.Z.) Ltd.,
46 Mercer Street, Wellington.
TELEPHONE:
Wellington 44-919.

●

AUCKLAND REPRESENTATIVE:
Mr. J. Kirk,
No. 11 Keans Building,
150 Queen St., Auckland.
Telephone 48-113. P.O. Box 401.
AUSTRALIAN DISTRIBUTORS:
Messrs. Gordon & Gotch (A/sia.) Ltd.

●

Remittances from Australia to New Zealand should be by international money orders or bank draft payable in New Zealand.

Sole Wholesale N.Z. Distributors FEATURE PRODUCTIONS LTD., P.O. Box 5065, Wellington.

Printed in New Zealand by H. H. Tombs, Ltd., Wingfield Street, Wellington.

"There are More Things in Heaven and Earth . . ."

Perhaps it is because we went to the film of *Hamlet* the night before we were due to write a page of editorial for the February, 1949, issue that we bethought ourselves of the crystal that amplifies as a subject on which to write. Perhaps not; but the fact remains that we were strongly reminded (although, as we were not giving a thought to radio at the time, it is doubtful whether the editorial pronoun is applicable) of the source of the above hackneyed quotation, along with several others, whose origin we would have known without thinking had we spent more time at school in paying attention to English lessons rather than becoming fatally interested in as much about radio as a school thought its boys should know—namely, elementary electricity and magnetism.

Some time ago, in April of 1947, to be precise, the American journal *Radio Craft* published an article by one who styled himself Mohammed Ulysses Fips, entitled "The Crystron Lapel Radio." In it was illustrated a receiver which, it was claimed, used a newly-invented device called by the author the Crystron. This, he explained, was a valve which used a special type of crystal detector, which by the addition of a third electrode was able to amplify, without the use of any batteries at all. The article was developed in the usual style of popular radio article, with numerous references to scientific literature, and, indeed, an "air of artistic verisimilitude" which made the reader, though he suspected from the start that something was not quite right, wonder whether this really was a serious article, or a hoax on the reader, or whether the author had simply succeeded in "taking in" the editor with a spate of quasi-scientific nonsense.

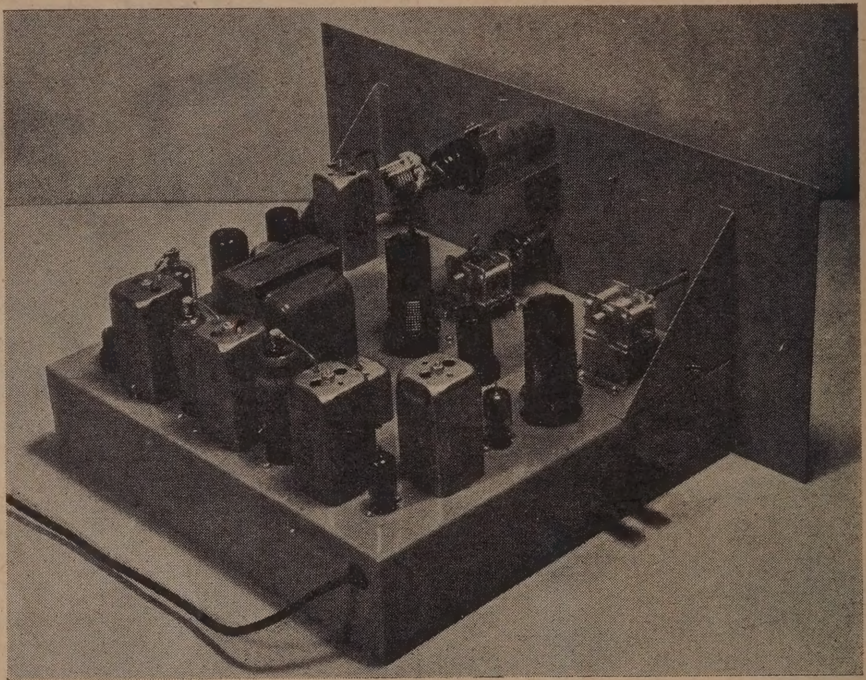
So well was the interest and the style sustained, that it was not until the last paragraph that the reader realized that the second possibility was the correct one, the date on the cover of the issue being April 1st!

There is not enough space here to enlarge to any extent on the claims made in the article referred to, and indeed such would hardly be worth doing were it not for information which has recently appeared in overseas publications not given to perpetrating humorous hoaxes on their readers! These reports state that a crystal amplifier *has* been developed, although not to the extent of doing so without the use of a battery. This device does not produce voltage amplification, but power amplification, and since it has a much lower output impedance than input impedance, the physical basis is one of current amplification, rather in the same way as a step-down transformer, with, of course, the exception that the latter gives a power loss, not a gain. In descriptions that have been published, the crystal amplifier is remarkably similar to the imaginary device described by Mr. "Fips" in *Radio-Craft*. This gentleman's crystal "triode" had a crystal and catswhisker, even as modern crystal rectifiers which have been described in these pages and elsewhere, and a third electrode, in close proximity to the point of contact of the catswhisker. The real one has two point-contacts, very close together, and while the imaginary one was supposed to work by some mysterious capacity effect, the real one functions through an effect that is not properly understood as yet, whereby the presence of the "grid" electrode modifies the flow of current through the other point contact, this current having been supplied by a battery. It is apparently one of those effects which take place on a molecular scale, and to which molecular physics will ultimately supply the answer, as it has done for other previously unexplained phenomena.

Shakespeare can be reckoned unfortunate that some of his sayings are so universally true as to become just as universally hackneyed, as, for example, the one from which our title is drawn; but that does not make them any the less universally true, and what a detective writer might call "the Queer Case of the Crystal Amplifier" is an entertaining example of its application. What kind of age do we live in when the wildest fancies can turn to established facts overnight?

The "Junior" Communications Receiver

For some time we have been promising our readers that we would present in these pages a communications receiver of good performance, and suitable for amateur constructors to tackle. At last the necessary work has been completed, and we have much pleasure in presenting the first specially designed receiver for short-wave reception only that has yet appeared in this journal. It has a number of novel and interesting features, and has been called the "Junior" Communications Receiver because it has been designed not only with an eye to excellence of performance, but especially for the benefit of those who may be new to the construction of multi-valve receivers.



Introductory

One of the difficulties confronting anyone who sets out to build a receiver for shortwave reception is to decide what sort of set it shall be, apart from the generally desirable one that its performance must be as good as possible. That is to say, is it to have one R.F. stage, two, or none? Is it to have plug-in coils, or band-switching? Is it to have single-signal selectivity, and if so, is it to incorporate a crystal filter or regeneration? These and a host of other questions must be answered before even a start is made to put circuits on paper, or to decide on a valve line-up.

All this is bad enough when considered from the point of view of an individual who is to build a receiver for himself, but is a hundred times worse for us, who must try to design something that will appeal not to one man but to as many as possible. People who build their own equipment must necessarily have their own ideas of what features they want most for themselves, so that whatever receiver we publish will have some features which appeal to some, and others which will not attract the same people. The difficulty of deciding just what sort of receiver would please the greatest number of our readers has therefore been in no small way responsible for the fact that so long has elapsed before a communications set of any kind has been presented. Thus, after a great deal of deliberation, it was decided that the answer was not a single receiver at all, but a series of them, presented over a period, and in all making use of most of the features that are to be desired. In this way, any one set can clearly not possess all the desirable characteristics that anyone may want, but each will be a good one in its class, and will no doubt appeal to a number of our readers. Also, there will be nothing to prevent readers from making up composite circuits embodying some details from one set, and others from another.

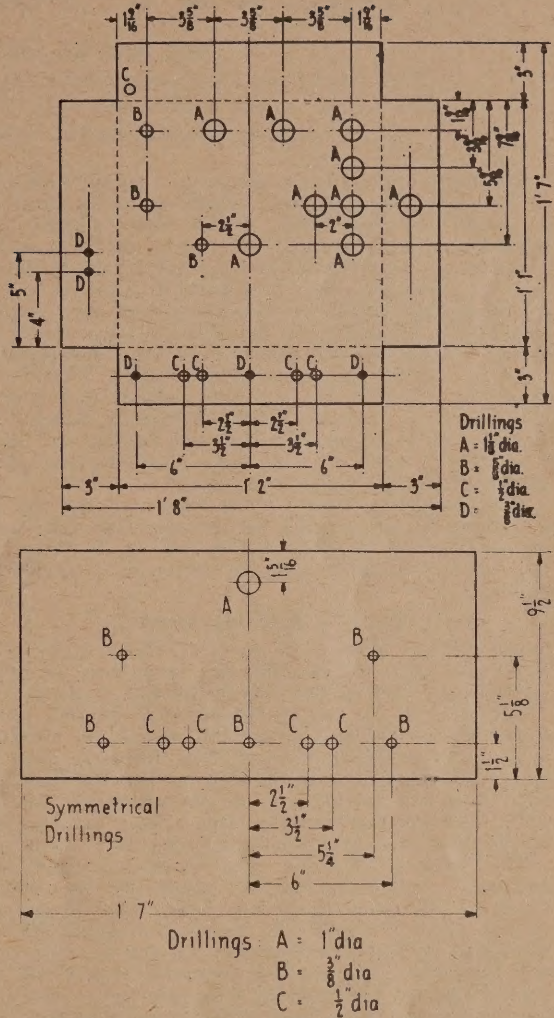
Object of this Receiver

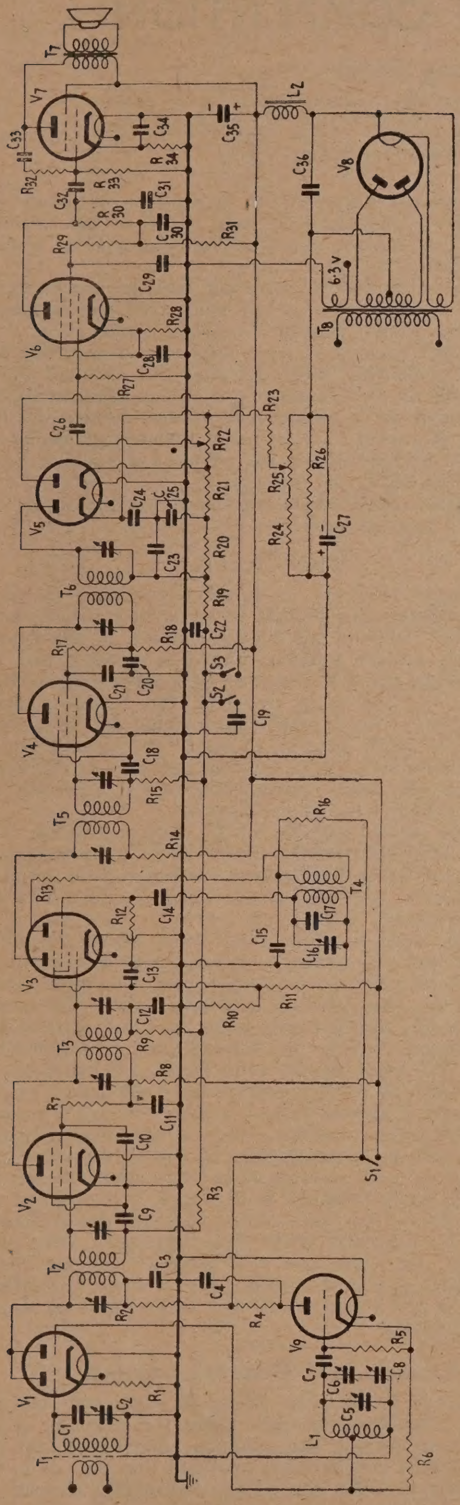
In some ways, the set to be described here will be the simplest of the series. This is not to say that it is a small set, or that its performance will be inferior in any way. As mentioned above, it has been designed specially for those who may not have had a great deal of experience in building multi-valve sets, and to a large extent this fact colours the general design. In spite of this, the set is easy to handle, has as much sensitivity as can be used, and is more selective than most. It incorporates a B.F.O., manual and automatic gain controls, an automatically adjusted noise limiter, and a switch by means of which a short or long time constant can be selected for the A.V.C., enabling the latter to be used on C.W. reception as well as on phone signals. As well as all this, it has provision for calibrated bandspread on a number of bands.

This makes quite an impressive list, and it is only fair to detail also some of the set's limitations, if they can be called such, since they have been introduced purposely so as to make the construction as non-critical as possible, while sacrificing little or nothing in the way of performance.

Into this category come (*a*) that there is no R.F. amplifier stage, (*b*) that plug-in coils are used, and (*c*) that the tuned input circuit is not ganged with the oscillator circuit. There are those who will not accept the fact that a receiver which has a triode mixer has no feed for an R.F. amplifier stage. We are definitely

(Continued on page 45.)





Above: Working drawings for chassis and front panel. Left: Circuit diagram. Full valves and a complete technical description of the circuit will appear in our next issue. The valve line-up is as follows:—

V_1, 6J6 or ECC91.
V_2, 6BA6.
V_3, ECH35.
V_4, EF39 or 6K7.
V_5, 6H6 or EB34.
V_6, 6J7 or EF37.
V_7, 6V6.
V_8, 80 or 5Y3-GT.
V_9, 6C5 or 6J5.

THE "R & E" PORTABLE COMPETITION

Mr. Ian M. Ogilvie's Winning Entry

(This article, and the drawings belonging to it, constituted the winning entry in the above competition. So that readers may judge the quality of the winner's entry, the drawings have been reproduced from Mr. Ogilvie's originals without retouching.—Ed.)

The first essential in the design of a portable receiver is that the designer satisfies himself as to the meaning, or rather the implication, of the term "portable" as applied to a radio. Literally, of course, the term means "capable of being carried," but by that definition, almost any set is portable unless it is screwed to the floor. The conditions laid down for this competition have gone a step further by setting out the technical requirements of such a receiver, but it is submitted that the ideal portable must be capable of being carried *easily*. That is, it should be small enough, and light enough, that it need not constitute a separate article or luggage, and can be slipped into the week-end bag, still leaving one hand free to cope with the golf bag, tennis racket, alpine stock, gallon jar, or what have you.

The designer of such a set is faced with the task of extracting the best possible performance from the smallest possible cubic capacity, and in order to do this, some degree of compromise must be reached on a number of points.

Choice of Components

Not the least of these points is the choice of batteries to be used, since it is the batteries, more than any other single item, which govern the overall size of the set.

The 77½-volt Eveready "Minimax," Type 467, seems to be the logical choice for the "B" supply, for although it is somewhat less economical, both from the point of view of battery life and initial cost, than the considerably larger 45-volt type, it has the advantage that the DL92 tube operating with a plate voltage of 67½v. has almost three times the output it has with 45v.

The same problem of space versus economy and battery life arises with the "A" supply—all the standard types of "A" battery are rather bulky, whereas the use of two standard torch cells enables the overall size of the set to be kept to a minimum. Of course, these cells will have to be changed more frequently than would the larger batteries, but provided a suitable clip is placed in an accessible position, there should be no difficulty from this quarter. Further, replacement torch cells can be obtained from most small stores and dairies during the week-end, whereas the standard "A" batteries are usually stocked only by radio dealers.

The speaker is another item which has a very direct bearing on the size and performance of the set. It is well known that large speakers operate much more efficiently than small ones, but when space and cost must be considered, the Rola Model 3c seems to meet the requirements as well as any other speaker available. If the speaker is set down in the chassis, and the output transformer mounted on a simple bracket on top of the voice-coil assembly, the whole unit is very compact and no space is wasted.

The choice of the remaining components presents no great difficulty.

Valves are of the miniature button-base type; in the design submitted, the Philips series have been used, but they can be replaced by the corresponding American types without changing the circuit.

In the I.F. amplifier, the new Swan Electric Co. midget coupling units have been used. If it is desired to use conventional transformers, it may be necessary to enlarge the chassis slightly, and increase the overall height of the cabinet, depending on the type of transformers chosen.

The loop aerial and oscillator coil used are the smallest available, in Wellington at any rate, and were supplied by Messrs. Radio Supply Co., 126 Featherston St., Wellington. The loop is air-wound and is mounted by means of a bakelite strip carrying the terminal lugs, which spans the self-supporting winding. The oscillator coil is wound on a midget polystyrene former of the type used in some I.F. transformers, and is permeability tuned, thus permitting the use of a fixed padding condenser (a further saving in space).

All resistors and condensers should, of course, be of the smallest type available.

The Circuit

The circuit (Fig. 1) is quite conventional in most respects, and employs an R.F. stage, with untuned coupling between its plate and the grid circuit of the mixer stage. This system provides ample sensitivity, and as well as saving the extra expense of a three-gang tuning condenser, the use of a two-gang one leaves a very useful space in which a planetary drive to the tuning knob can be fitted. This is a feature not usually found in midget portables, but is well worth while, as this type of set is usually fairly sharp in the tuning, especially at the high-frequency end of the dial.

It will be noticed that no A.V.C. is applied to the I.F. amplifier—this does not impair the A.V.C. characteristic of the circuit, but it does make the wiring a little simpler, and saves using a filter resistor which would otherwise be necessary in the A.V.C. line.

The only other part of the circuit which calls for special reference is the output stage, where special attention has been given to quality. It will be noticed that instead of the usual 500-ohm back-bias resistor, 750 ohms has been used; this not only helps to reduce distortion, but also slightly reduces the battery drain. (Incidentally, the total "B" drain at 67½ volts is about 9 milliamps.) Also, in order to further reduce audio distortion, negative feedback is applied from the voice-coil to the screen of the first audio amplifier. This arrangement reduces the audio gain to some extent, but still leaves plenty in hand, and is well warranted by the improvement in quality. To apply feedback in this way, it is essential to earth one side of the voice-coil—which side can be found out only by trial and error. Since there are only two alternatives, the right one will be quite obvious from the reduction in volume and the improvement in quality, especially if the volume control is turned well up while the trial is made.

Chassis and General Lay-out

The chassis is made of 22-gauge steel, and has no ends—a ¼" flange at the ends makes the assembly quite rigid. If sheet steel is not available, galvanized iron of the same gauge can be used, provided that any spots to which solder is to be applied are thoroughly cleaned.

Figure 2 shows the size and position of all major

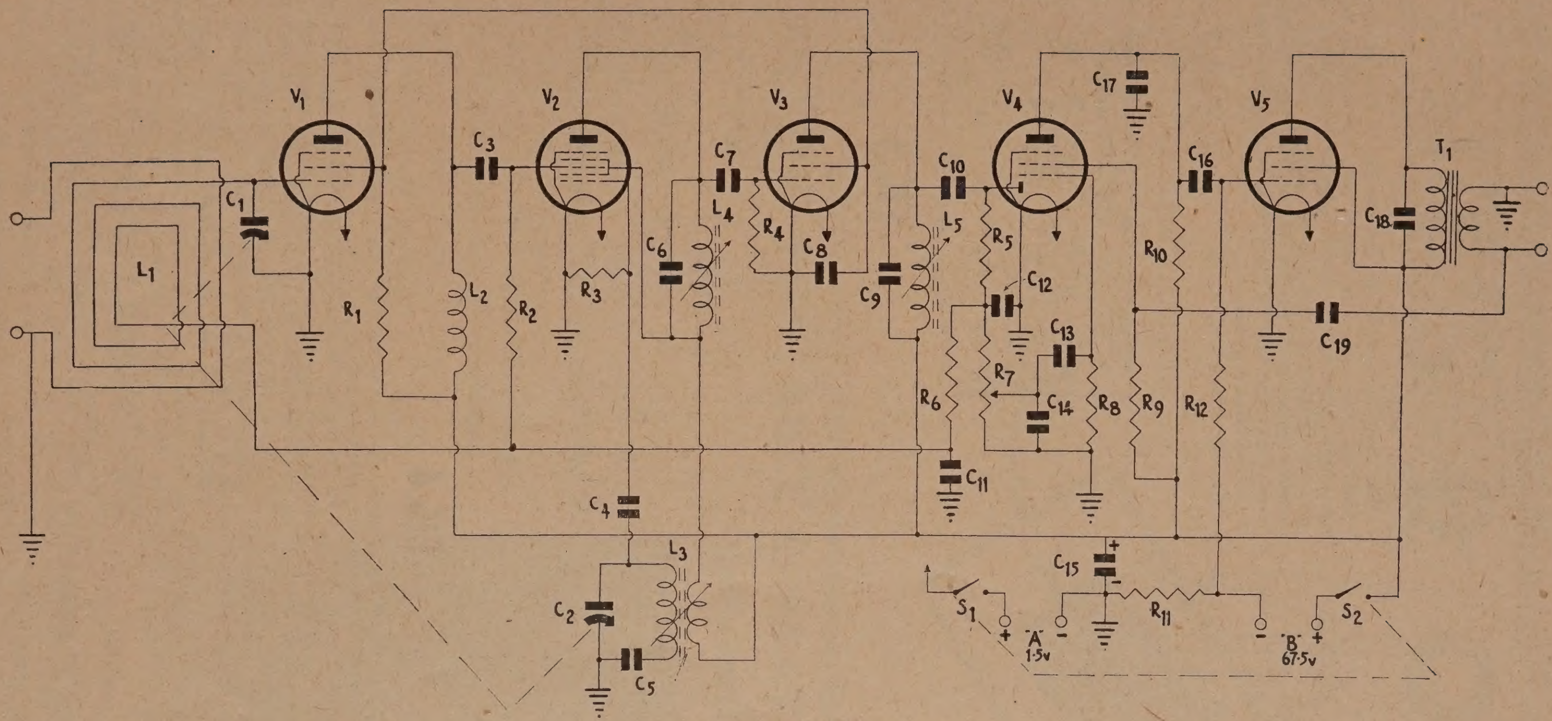


FIG. 1

List of Components

Condensers:
- $C_{1, 2}$, midget 2-gang tuning condenser (incl. mica trimmers).
- $C_{3, 4, 12, 17}$, 100 $\mu\mu$f.
- $C_{6, 7, 9, 10}$, 100 $\mu\mu$f. silver mica (supplied with I.F. units).
- C_5, 400 $\mu\mu$f. fixed padder.
- C_8, 0.05 μf. paper
- C_{11}, 0.02 μf. paper.
- C_{13}, 0.001 μf.
- C_{14}, stray wiring capacitance (see text).
- C_{15}, 8 μf. midget electro.
- C_{16}, 0.005 μf.
- C_{18}, 0.002 μf.
- C_{19}, 0.05 μf. paper.

Valves:
- $V_{1, 3}$, DF91.
- V_2, DK91.
- V_4, DAF91.
- V_5, DL92.

Resistors:
- R_1, 200,000 ohms.
- $R_{2, 10}$, 1 meg.
- R_3, 100k.
- R_4, R_{12}, 2 meg.
- R_5, 250k.
- $R_{6, 9}$, 3 meg.
- R_7, 1 meg. pot. (small).
- R_8, 10 meg.
- R_{11}, 750 ohms.

Coils:
- L_1, Loop antenna.
- L_2, R.F. choke.
- L_3, oscillator coil, 465 kc.
- $L_{4, 5}$, I.F. coupling units.

Transformers:
- T_1, output transformer.

Switches:
- $S_{1, 2}$, D.P.S.T. toggle.

mounting holes. Screw holes should be drilled according to the size of screws and type of sockets being used.

The cut-out for the speaker can best be made by drilling small holes round the outline of the cut-out, cutting between the holes with a small, sharp cold chisel and cleaning up the edge with a half-round file. In this connection, it is a good idea to first make a template from thin card to fit the speaker, and use this in marking out the chassis.

The dotted lines in Fig. 2 represent right-angle folds.

Mounting Components

The positions of the main components mounted above the chassis are shown in Fig. 3.

The "Polar" midget tuning condenser can be soldered on to the chassis without any difficulty, and this saves making and mounting a rather awkward bracket. The upper two mounting bushes on the front of the condenser are used for mounting a bracket to carry the dial scale. The dial pointer can be made from a piece of celluloid or thin perspex, and attached to the front of the low-speed member of the planetary drive by means of two small tabs sweated to the sides of the member, and folded to hold the pointer in place. The locking tab of the planetary drive can be fixed to the top of the chassis by a spot of solder.

The speaker is held on the chassis by the lower two mounting holes only—the upper ones are used to mount the output transformer bracket. In order to avoid damage, the speaker should not be mounted until all other constructional work on the chassis has been completed. Even then, it is wise to cover the front of the cone with a stiff cardboard protector.

Of the two holes in the front of the chassis, the upper one is for the D.P.S.T. switch, and the lower for the volume control.

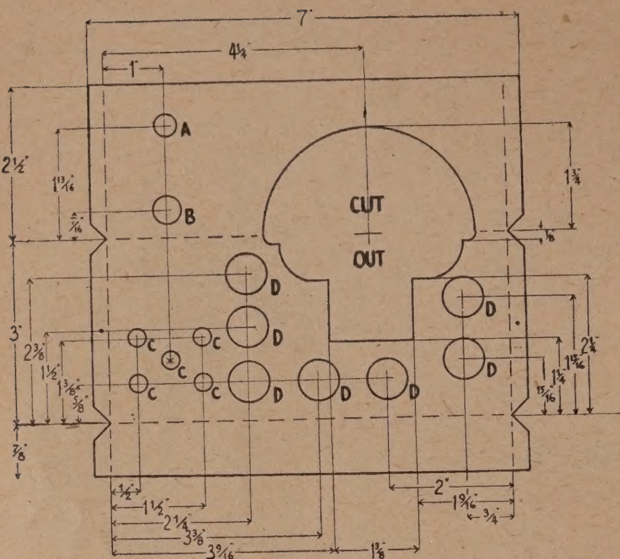


FIG. 2 DRILLINGS

A = 3/8" dia. B = 7/16" dia.
C = 1/4" dia. D = 5/8" dia.

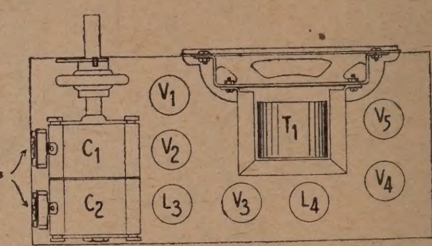


FIG. 3

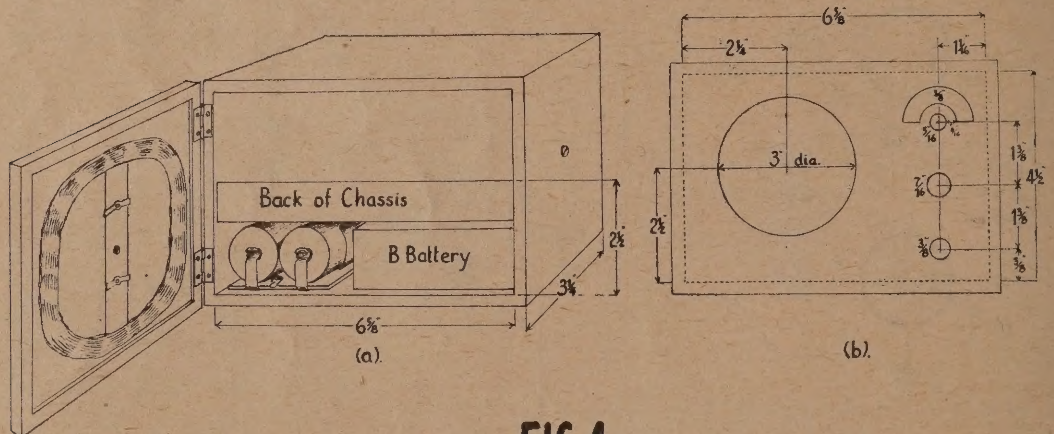


FIG. 4

In mounting the sockets for the plug-in I.F. units, considerable space can be saved by cutting down the bakelite wafers and using the eyelet holes for mounting.

Of course, all valve and I.F. sockets should be oriented to ensure that grid and plate leads are kept apart, and as short as possible.

The oscillator coil is situated under the chassis, as near as possible to the oscillator-mixer valve, directly below the oscillator section of the gang. It can be mounted by means of a short piece of terminal strip and two right-angle lugs, one soldered to the underside of the chassis, leaving the other at such a distance from the chassis that the coil can be fitted in and attached by one of the polystyrene lugs of the former. The "pigtail" leads from the coil can be taken direct to the appropriate connections.

(Concluded on page 48.)

A Panoramic Adaptor Unit for Amateur Transmitters and Others

Part 1 of this article described the principle of operation of the panoramic adaptor in general terms, and gave the circuit of a unit which can be used with a receiver and an existing oscilloscope. This part goes on to discuss the circuit in detail, and to show the power supply arrangements needed if the C.R.T. is to be built into the unit, as was done in the prototype.

PART 2

Details of the Circuit

The circuit of the adaptor, minus only its power supply and the connections to the cathode ray tube, was given in the first instalment of this article. The circuit and component list is reproduced here for the benefit of those who may not have seen the last instalment, and so that the two copies of the journal will not have to be on hand when this one is being read.

V_1 is a 6K8, and is the mixer shown on the block diagram. Its circuit is conventional, except, as was mentioned before, for the fact that the 465 kc/sec. input transformer has its windings de-tuned on either side of this frequency, so as to widen the pass-band of the adaptor as a whole. The oscillator circuit is also quite usual in itself, and uses the ordinary tickler-feedback arrangement, so as to make use of the triode portion of the 6K8. It should be noted that the grid winding has been isolated from ground as far as D.C. is concerned, in order to allow the plate voltage to be applied, through the winding, to the reactance modulator, V_2. The oscillator coil is not a standard component, of course, but can easily be made from one winding of a 175 kc/sec. bobbin, suitably modified in a manner to be described later.

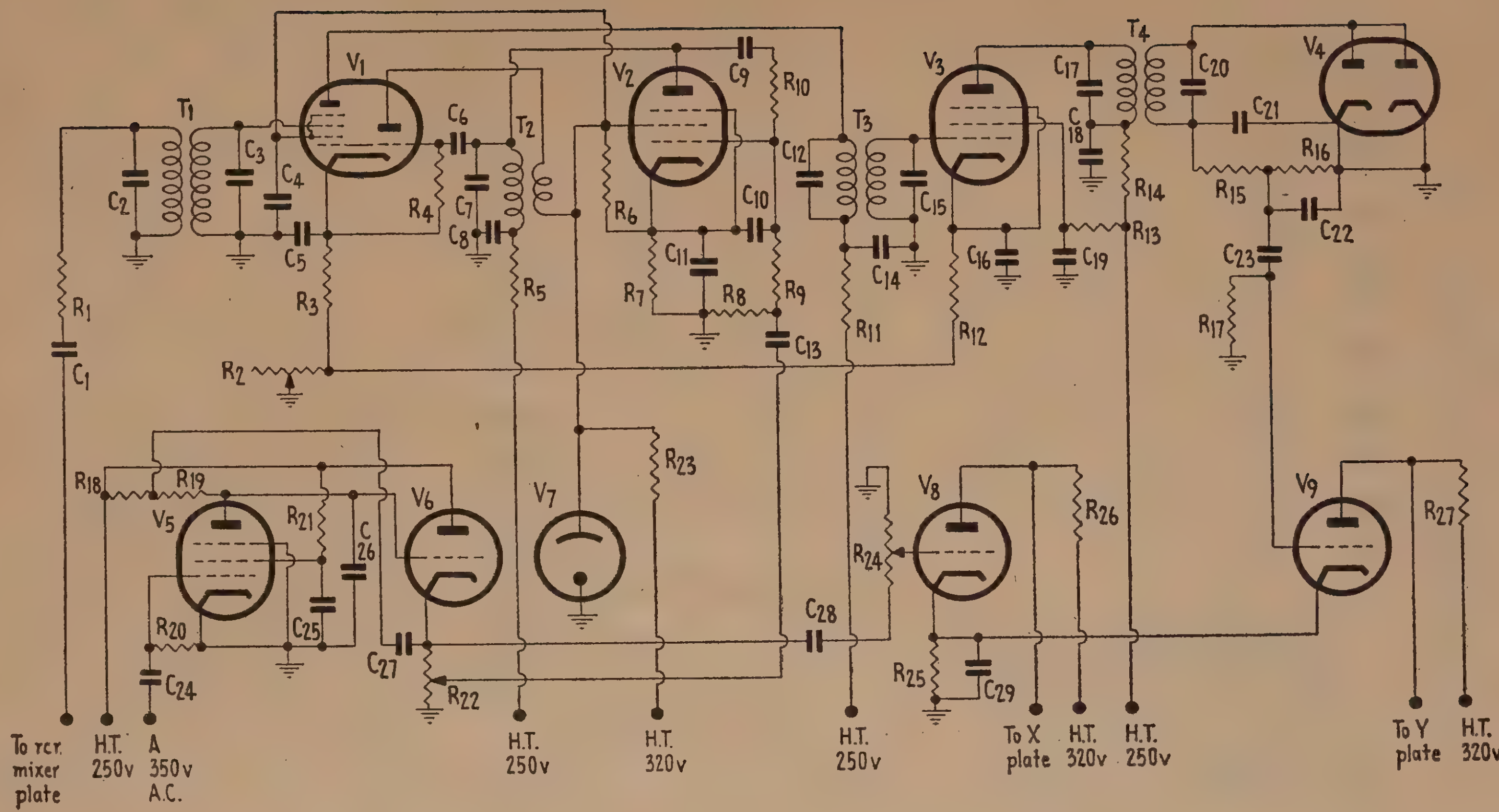
The 100 kc/sec. I.F. amplifier stage is V_3, which is a 6K7. T_3 and T_4 are 100 kc/sec. I.F. transformers, which are now available on the market from at least two manufacturers. In all respects the I.F. stage is conventional. As can be seen, the adaptor does not use automatic volume control, as this would defeat the purpose of the unit. Without A.V.C., it is possible to observe the relative signal strengths of those that are visible, and also to obtain an estimate of the effectiveness of the receiver's A.V.C., by comparing the fluctuations of the visual signals with the audible fluctuations from the loudspeaker. Also, if the adaptor had A.V.C., the number of signals present, and their total strengths, would affect its sensitivity, and this would serve no useful purpose. Instead, manual volume control is used. This works on all signals displayed, but since only one at a time is being examined in detail, this does not matter. For example, using the manual gain control, it is possible to remove from the screen the majority of signals that are present when the one being examined is a strong one, or to bring up the amplitude of a weak one to a level that makes it easy to watch. In addition, a very strong signal might have its peak right off the screen unless a gain control is available. The control is the usual type of variable cathode-resistor, working on both mixer and I.F. stages. One reason for the choice of the 6K8 for the mixer is that when its gain is controlled, either manually or automatically, there is no noticeable shift in the frequency of the oscillator. In an ordinary receiver this effect is annoying enough, as it can cause a short-wave signal to become badly detuned. In a panoramic adaptor, however, it is even more undesirable than in a receiver proper, because the result is visible on the screen as a shift in the frequency of the signal, whereas in fact none has occurred. The use of the 6K8 caused this effect to be so small as to be unnoticeable.

The second detector is a 6H6, with sections in parallel. It would have been possible to use a double-diode-triode in this position, but doing so would not have decreased the total number of valves necessary, so it was decided to use the separate detector valve. The audio output of the detector is fed, without the interposition of an audio gain control, to the grid of V_9, which is a resistance-coupled amplifier stage, using one-half of a 6N7 double triode. This valve can be regarded as the output stage, since it feeds the output of the adaptor to the Y plate of the cathode ray tube, causing each signal to show as a vertical deflection as the oscillator frequency sweeps past it. If an external 'scope is used there will be a blocking condenser at the input to the amplifier, if it is used, or between the Y plate terminal and the plate itself, if the built-in amplifier is not used. If the C.R.T. is built into the adaptor unit, in the manner to be described, no blocking condenser is used, and the plate of V_9 is directly connected to the deflecting plate.

The circuit which produces the saw-tooth deflecting voltage, which also modulates the 365 kc/sec. oscillator, comprises V_5 and V_6. The former is a 6SJ7. Examination of its circuit will show that apart from having no bias resistor, or indeed any obvious source of bias at all, it is connected as a resistance-coupled audio amplifier. The plate load resistor, made up of R_{18} and R_{19}, in series, is split into two equal parts, and there is a large condenser connected from its plate to earth. The purpose of this valve is to shape the 50 c/sec. input voltage from the high-voltage secondary of the power transformer, in the proper way. If the condenser C_{26} were removed, the wave-form at the plate of V_5 would be approximately a square-wave, with the positive-going portion long compared with the negative-going portion. Otherwise it could be described as a series of short negative-going pulses, recurring at the frequency of the input voltage, which is 50 c/sec.

Some readers will no doubt be appalled at the size of the input voltage applied to V_5, namely 350v. A.C. Such a thing is unheard of in most applications of small valves, but is commonplace in pulse circuits, where the first step is to "square off" a sine-wave voltage. It will be noted from the component list that the grid-leak, R_{20}, has a value of 5 megohms. The grid thus acts as a shunt rectifier, so that a high negative voltage appears at the grid terminal of the valve, due to the flow of grid current. As a result, the grid is actually biased negatively for most of the input cycle, and only goes positive for a very small fraction of the time. For the same reason, the positive voltage reached by the grid while it is conducting is also very small. This is because the negative bias developed by the grid current is almost equal to the *peak* value of the A.C. input voltage. In fact, we have the seemingly anomalous situation where a very large A.C. voltage applied to the grid of the valve allows it to conduct for about only 1/20th of the time, and the

(Continued on page 37.)



COMPONENT LIST

R_1, see text.
R_2, 25k. pot.
R_3, 250 ohms.
R_4, R_9, R_{10}, R_{15}, R_{22}, 50k.
R_5, 2k.
R_6, R_{23}, 10k.
R_7, 300 ohms.
R_8, R_{26}, R_{27}, 250k.
R_{11}, R_{14}, 5k.
R_{12}, 350 ohms.
R_{13}, R_{18}, R_{19}, R_{21}, 100k.
R_{16}, 500k.
R_{17}, 1 meg.
R_{20}, 5 meg.
R_{24}, 500k. pot.
R_{25}, 3k.
C_1, see text.
C_2, C_3, C_{12}, C_{15}, C_{17}, C_{20}, I.F. trimmers.
C_4, C_{19}, C_{23}, 0.05 μf.
C_5, C_8, C_{14}, C_{16}, C_{18}, C_{24}, 0.1 μf.
C_6, C_{10}, 50 $\mu\mu$f.
C_7, 3–30 $\mu\mu$f. Philips trimmer.
C_9, C_{21}, C_{22}, 250 $\mu\mu$f.
C_{11}, 50 μf. electro.
C_{13}, C_{25}, C_{27}, C_{28}, 0.5 μf.
C_{26}, 1 μf.
C_{29}, 25 μf. 25v. electro.
T_1, 465 kc/sec. I.F. transformer.
T_2, 365 kc/sec. osc. coil (see text).
T_3, T_4, 100 kc/sec. I.F. transformers.
V_1, 6K8.
V_2, 6SJ7.
V_3, 6K7.
V_4, 6H6.
V_5, 6SJ7.
V_6, 6AC7 (triode-connected).
V_7, VR150/30.
V_8, ½6N7.
V_9, ½6N7.

A Five-inch Oscilloscope Employing Unit Construction

PART 4 FURTHER USES FOR THE COMPLETE OSCILLOGRAPH

Measuring Phase-shift in Amplifiers

Differences of phase can be measured very readily with the cathode ray oscilloscope. In audio work, phase-shifts are not of much consequence as far as the reproduction of music is concerned, because the ear appears unable to distinguish between complex waveforms which have the same percentages of harmonics, but in which the phase of the harmonics is shifted, compared with the original. However, in amplifiers which employ large degrees of negative feedback, phase-shift becomes important, because it is this that causes the feedback at high and low frequencies to turn round and become positive in direction, with possible oscillation. In fact, if an attempt is made to place too much feedback round a multi-stage amplifier which has a high phase-shift, either at low or high frequencies, or both, oscillation *will* occur, as many have found to their cost. In order for the feedback to change from negative to positive, it is not necessary for the phase-shift to be as great as 180 degrees, so that it is possible to have this particular form of instability when the feedback is applied round only two stages of an amplifier, although it is by no means likely, because with only two stages, the gain is not usually great enough, at frequencies where much phase-shift occurs, for oscillation to take place. With feedback round three stages, however, the situation is different, in that a total phase change of 270 degrees is now possible, so that the necessary amount of gain is likely to be available at frequencies where the shift is greater than 90 degrees. It thus becomes important to know at what frequencies given amounts of phase-shift take place. To do this, all that is needed is the oscilloscope, and a table of sines. If two voltages of identical frequency are placed on the X and Y plates of the oscilloscope, the pattern obtained depends on the phase difference between the two voltages. If connections are made so that positive voltages deflect the spot upwards on the Y axis, and to the right on the X axis, then the picture when there is no phase difference is a straight line sloping upwards from left to right. The fact of zero phase difference is shown by the straight line pattern, and the slope of the line depends only on the relative amplitudes of the voltages. If they are equal, the slope is 45 degrees. If the Y deflection is greater than the X deflection, then the line must slope at an angle to the horizontal, greater than 45°, while if the reverse is the case, the slope is less than 45°. As the phase difference changes from zero to a small value, the straight line gradually opens out into a narrow ellipse, or oval, still sloping in the same way as the line did. As the phase difference becomes greater, the ellipse becomes rounder, until when the difference is exactly 90° the ellipse becomes a circle. It should be remembered that even if the phase-shift is exactly 90°, the picture will still be an ellipse unless the amplitudes are equal. As the phase difference is increased past 90°, the ellipse leans over in the opposite direction—this time upwards from right to left, and at 135°, is inclined at 45° to the horizontal once more. When the shift is exactly 180°, the pattern is again a line, and is inclined at 45° to the horizontal as long as the amplitudes are still equal.

At this point, as further phase-shift is introduced, the pattern goes through the same changes as above, but in the reverse order, till at 360°, or a whole cycle of shift, the pattern is indistinguishable from that for 0° shift. All this might sound rather complicated, but in practice it is not. As long as it is remembered to connect the voltages in the right way, and that to recognize shifts of 45°, or multiples of this, it is necessary to have equal amplitudes on the two sets of plates, there will be no difficulty. Another simple rule which gets rid of a deal of possible ambiguity is that each stage of amplification cannot produce more than 90° of phase-shift. At least, if it is resistance coupled. Transformers complicate the issue rather.

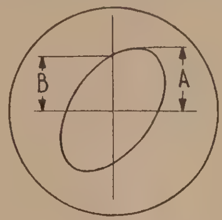


Fig. 5.

How to Measure Phase-shift in Degrees

The exact amount of phase-shift present in any one case is easily measured as follows. First, the output of the amplifier to be tested is applied to the Y plate or plates. If the amplifier has a push-pull output stage, both Y plates are used, one valve plate being connected to each. If it is a single-ended amplifier, one of the Y plates is earthed, and the other is connected to the plate of the output stage. Remembering our warning above, the correct plate to use for applying the signal is the one which gives an upward deflection for a positive voltage.

The next step is to connect the output of the test oscillator to the X plates. Here it is unusual for the oscillator to have balanced output terminals, in which case it will be necessary to use the single-ended connection to the 'scope. The maximum available output voltage should be applied to the X plate, and a voltage divider used to reduce the input to the amplifier to the right value. That is, so as not to overload the amplifier. The amplifier gain control can usually be used for this purpose.

It will now be found that when the amplifier is working, the Y deflection will be much greater than the X deflection, since the oscillator output is usually only a few volts, while the amplifier output may be over a hundred quite easily. One way out of the difficulty is to reduce the input to the amplifier, still feeding the X plates from the maximum output of the oscillator. This method works all right as long as the X voltage is large enough for the deflection to be reasonably large. If it is not, the 'scope amplifiers have to be used, which is a disadvantage, and will be discussed a little later. We will therefore assume for the moment that the oscillator output is large enough to give a reasonable deflection on the screen.

The input to the amplifier is first disconnected, and the amplitude of the remaining X deflection measured. Then the input is applied to the amplifier, and the X-plate connection is broken while the amplifier input is adjusted until the Y deflection is the same as the previously-mentioned X deflection. The X-plate connection is then re-made, and we are ready to measure the

phase-shift. Suppose the pattern is as in Fig. 5. The vertical and horizontal lines are not part of the pattern, of course, but represent the individual deflection voltages after the above adjustment has been made. In other words, they are the axes of the graph. Since they are needed for the actual measurement, it is perhaps best to draw them in first. They can be drawn on a piece of transparent paper and pasted on to the face of the tube, or else they can be drawn on a piece of celluloid which is supported in front of the tube. Before starting the adjustments already described, it is then only necessary to shift the undeflected spot with the shift controls until it is exactly at the intersection of the two lines.

Fig. 5 thus represents the trace, and the axis lines as well. When this picture has been obtained, the amount of phase shift can be found from the formula:—

$$\sin \theta = B/A$$

where θ is the angle of phase-shift, in degrees, and B and A are the measurements shown in Fig. 5.

In practice, actual measurement is not often required, but a visual indication of what frequencies are much affected by phase-shift is. It will be found, as soon as this method is tried, that the frequency at which the phase-shift is zero is very easily and very accurately determined, because it is so easy to tell when a narrow ellipse turns into a straight line. Needless to say, there is only one frequency at which an amplifier has zero phase-shift, and for estimating the overload point of an amplifier this frequency should be used. The connections are the same as described for the phase-shift test. Once this frequency has been found (and doing so is simply a matter of spinning the oscillator frequency control until the straight-line picture is found), it can be seen that for frequencies higher than this the phase-shift is in the opposite direction from the shift which takes place at lower frequencies.

The "phase-shift picture" as the patterns are called that we have just been dealing with is a very useful one apart from the simple observation and measurement of phase-shift. It is used (at the zero-phase-shift-point) for estimating the onset of distortion, and even for measuring the percentages of various harmonics by a simple method which will be described. It is therefore quite an important one in audio work, and shows how useful the oscilloscope can be, without the use even of amplifiers or a time-base.

Using the 'Scope Amplifiers in Getting the "Phase-shift" Picture

It was mentioned above that if the oscillator has not sufficient voltage output to operate the X plate directly, it will be necessary to use the 'scope amplifiers, in spite of the fact that this is to be avoided if possible. What, then, are the disadvantages complained of?

The main one is this: that it is not possible to build amplifiers which have no phase-shift at all, and if we are investigating the phase-shift behaviour of an amplifier, it is clearly necessary for the 'scope amplifiers, if they are used, to have no phase-shift at all. At this rate, it would appear that it is not possible to use any amplifiers other than the one under test. Luckily, however, this is not so. A little thought will show that the requirement is not so stringent as all that, *as long as identical amplifiers are used both for the X and Y deflections.* What the C.R.T. displays, when used in this manner, is the *difference* in phase between the two test voltages. Thus, if the amplifiers used with the two axes have *identical* phase-shifts, the true picture will be preserved. Suppose, for example, that the phase difference between the test voltages is 45°. Suppose, further, that only one 'scope amplifier is used, on the X axis, to bring the X deflection to a large enough value. If this amplifier has a phase-shift of, say, 10° *itself,* at the test frequency, the result will be an observed phase difference of either 35 or 55°, according to whether the 'scope amplifier's phase-shift is in the same direction or the opposite one to the shift occurring in the amplifier under test. Suppose, however, that we have two identical 'scope amplifiers, to the extent that their phase-shifts at any one frequency are identical, and that we use the second one between the output of the amplifier under test, and the C.R.T. Y plates. This time we have introduced identical phase-shifts into both voltages, so that the difference between the two is still the same as before the amplifiers were inserted.

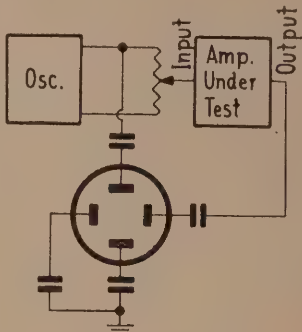


Fig. 6.

It is for this reason that the two amplifiers in the amplifier and time-base unit have been made the same in all respects. The differences between their degrees of phase-shift at various frequencies are negligible and so are the differences in gain, in spite of the fact that the valves and resistors were not specially chosen so as to have identical characteristics for the two amplifiers.

When the amplifier unit has been built, a good test for both amplifiers is to connect the X and Y input terminals together, and to feed a signal from the oscillator into them. Since the same voltage feeds both amplifiers, any phase-shift shown on the screen must be due to the amplifiers themselves, and will be numerically equal to the difference between their individual phase-shifts at the test frequency. It will probably be found that over the audio frequency range, the phase difference is so small as to be negligible, but that it becomes appreciable at frequencies above 15 kc/sec. This is only to be expected, as it is here that the individual shifts are greatest, so that there is more chance of the difference becoming larger. In using both amplifiers in this way, it is preferable to take the input to the X amplifier from the same point as feeds the input to the test amplifier. This enables the phase-shift in the attenuator, if any, to be eliminated. The basic connection for the phase-shift test is shown in Fig. 6, but here we have drawn the amplifier output as going to the X plate, and the input voltage to the Y. This serves to indicate that for such tests, it really does not matter which set of plates is used for what, as long as one knows which is which.

Observing Distortion and Overload

This is an exceedingly useful function of the oscilloscope, and is a very simple one to apply. The connections between the amplifier under test and the oscilloscope are identical with those described for the phase-shift picture, and as stated above the pictures are really identical. The main difference is that for estimating when

(Continued on page 35.)

A New Family of High-Frequency Inductances

By E. B. MENZIES, Design Engineer, Johns Ltd.

Since tuned circuits are the real basis upon which radio receivers are designed, and largely the determining factor in their performance, it is perhaps interesting to remember that coils showing inductance are much older than radio itself. In fact, according to a 1925 publication by Morse, it was in 1890 that Sir Oliver Lodge first published the results of his researches in electrical resonance. Later workers in the field were quick to apply the phenomenon of electrical resonance to radio circuits, and development of inductances for radio frequency circuits reached an all-time high in America in 1925. In that year, according to a small booklet highlighting events in radio from 1914 to 1939, radio coils reached a new peak in unique design. Set builders had to choose from standard solenoid coils, pancake coils, spider-web coils wound on forms like the spokes of a wheel, honeycomb coils, toroidal or doughnut-shaped coils, binocular coils, bank-wound coils, random-wound coils, and even figure-of-eight coils.

It would appear from the above that very considerable effort has been made in devising these various inductance types, and it is interesting to remember here that the field of coil development is by no means complete. Since the history of coil development is almost a subject in itself, it will be sufficient to add here that from 1925 onwards the trend in tuning-coil design has been towards smaller and smaller units. Undoubtedly this was necessitated by public demand for smaller receivers, and by reason of the fact that more and more tuned circuits were included in receivers. Although designers endeavoured to keep coil efficiency high with reduced size, their efforts were not always successful, and it became common to increase the number of stages in the receiver to overcome deficiencies in selectivity and sensitivity. Altogether, their efforts were not too bad when one considers that it has only been in comparatively recent years that all the factors which make for losses in tuning coils have been tabulated.

Q FACTOR

Q factor is mentioned here since it has become the the measure of efficiency of tuning coils. The dream of all radio designers is to produce a coil which shows maximum inductance for the length of wire used, low self capacity, and zero resistance. Such a coil would show great selectivity and a theoretically infinite voltage magnification at resonance, in a single-tuned circuit. Since the problem is about as unlikely as perpetual motion, we will leave it, since a resistanceless conductor is not available. Actual losses in radio frequency coils are in the main due to eddy currents in the conductor, and the rather more complex losses due to the former or support upon which the coil is wound. Since Q factor expresses the ratio of reactance at the operating frequency to the R.F. resistance

$$\frac{2\pi fL}{R}$$

it becomes an accurate measure of coil efficiency.

COIL DESIGN TO-DAY

As far as New Zealand is concerned, it can be fairly stated that two of the most important factors to be considered by radio engineers are the availability of materials and the cost of production. In the design of efficient coils these are no small handicap. However, since a veritable mine of information is available on optimum wire sizes for various types of coils at the various frequency ranges, the only possible way to reduce coil losses is to concentrate on the former or support.

Common overseas practice is to use polystyrene or ceramic formers, the ceramics being generally favoured for their lower temperature co-efficient. Since neither of these materials is available here in any real quantity, and the cost of processing polystyrene former is relatively high, a certain amount of attention was devoted to polyvinyl chloride.

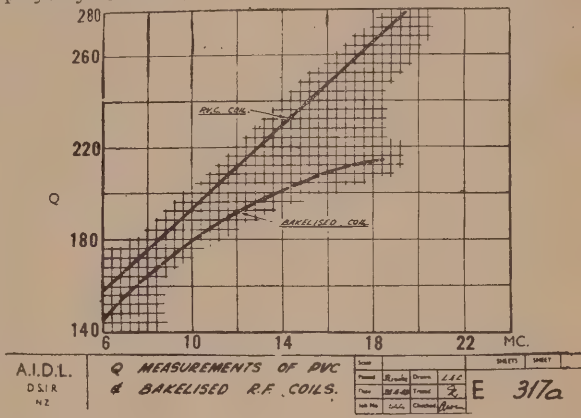


Fig. 1.—Curves of Q versus frequency for P.V.C. and bakelised coils.

POLYVINYL CHLORIDE (P.V.C.)

This material has become widely used as an insulator for wires and cables and has rightly earned very considerable popularity. While its insulating properties are beyond question, there is an almost complete lack of information on its losses or power factor at high frequencies. It has been fairly freely stated in this country (presumably mainly by experimenters) that P.V.C. has high losses at radio frequencies, but the real basis upon which such statements have been made is unknown. One modern text-book (*Reference Data for Radio Engineers*—Federal Tel. and Radio Corp.) gives relatively high power factor figures for P.V.C. at the lower frequencies but substantially lower power factor at the higher frequencies up to 100 megacycles. The power factor figures quoted by various authors show very considerable variation, and as this is presumably due to the percentage of plasticizer used in the manufacture, it was decided to wind coils with this P.V.C. covered wire and plot the efficiencies.

Early results were so heartening that a commercial process was developed for winding these coils and so sealing them that they become a solid mass. The primary and secondary windings as well as a small methylmethacralate mount are sealed in a complete unit (N.Z. Prov. Pat. 99100). The coils at present under manufacture for use in standard domestic dual-wave receivers are approximately $\frac{3}{4}$ in. long and the same in diameter. For purposes of direct comparison, the P.V.C. coil was compared with a standard shortwave coil wound

with the same gauge wire on a $\frac{3}{4}$ in. grooved bakelized paper former, impregnated in cerese wax. Q curves for the frequency range of 6 to 18 megacycles are shown in Fig. 1. These curves are self-explanatory, with the exception of the curve for the P.V.C. coil. The most obvious point is that the curve is a straight line, which indicates that the losses in the P.V.C. support are zero. In addition, it is no small achievement to secure a Q factor of 280 at 18 megacycles in an air-cored coil of these dimensions. As a matter of interest, the Q curve for an identical coil wound on polystyrene tubing shows negligible variation from the curve for the P.V.C. coil.

It would appear from these and subsequent tests that P.V.C. introduces negligible losses at frequencies up to 50 megacycles. This being so, it follows that the popular belief of the high losses in P.V.C. at radio frequencies is not based upon fact, and that P.V.C. may yet find very considerable application in the field of radio frequencies.

From the point of production cost and electrical efficiency, the P.V.C. coil will be extremely hard to equal. The so-called air-wound coil—supported on celluloid strips—appears inferior to the P.V.C. coil, probably on account of the relatively poor properties of celluloid at high frequencies. In any case, the air-wound coil would be ruled out on the matter of production cost, as would the coil wound on grooved polystyrene former.

MOISTURE ABSORPTION

Complete information is as yet not tabulated for the moisture absorption of the P.V.C. coils, but it may interest readers to know that tests have been made by immersing the P.V.C. coil and one wound on polystyrene former (doped with liquid polystyrene) in water for a period of 24 hours. The coils were removed from the water, the surplus dried off, and Q checks made. Neither coil showed the slightest reduction in Q factor after this treatment. Just whether P.V.C. is superior to polystyrene or not in this respect can only be determined by prolonged immersion in water, and tests are proceeding along these lines.

TEMPERATURE CO-EFFICIENT

It is not the purpose of this discussion to cover the subject of temperature co-efficients at length. According to Terman (*Radio Engineers' Handbook* and *Radiotron Designer's Handbook* and many other well-known texts) temperature co-efficient in radio coils is nearly always positive. That is, inductance increases with rising temperature. The same holds for most mica condensers and for gang condensers of the type used in domestic receivers—their capacity increases with rising temperature. In nearly all cases the frequency drift in receivers due to temperature rise is towards a lower frequency. In the P.V.C. coils this relation does not hold. P.V.C. itself expands substantially with temperature, and, furthermore, has a high positive temperature co-efficient of its di-electric constant. Subjecting the P.V.C. coil to heat has the effect of expanding the turns apart and so decreasing the inductance. Since the self capacity of the coil is dependent upon the di-electric constant of P.V.C., temperature rise increases the di-electric constant and the self capacity. For a coil of about $\frac{3}{4}$ in. long and $\frac{3}{4}$ in. diameter, this increase in self capacitance is insufficient to offset the effect of the decreasing inductance, and the coil exhibits a negative temperature co-efficient. This should to some extent neutralize the effect of increasing capacities in the circuit and make for a smaller thermal drift in receivers. Just whether it would be possible to so proportion a coil that rising self capacitance would offset decreasing inductance is a problem for consideration. It does appear that such a coil could be designed for single-frequency operation only for the same reasons as capacity correction with negative temperature condensers is effective at one frequency only. (*Electronics for Engineers,* page 88.) Rough tests have been conducted to determine the results of temperature cycling—in other words, to determine whether the coils suffer any permanent change in inductance after being subjected to rising temperature. Present indications are that the inductance remains perfectly stable, under temperature rise conditions such as would be encountered in standard types of radio equipment. Incidentally, this is a point which cannot be sustained by some coils wound on bakelized paper former.

APPLICATIONS

Undoubtedly the new P.V.C. coils will find wide applications in both receivers and transmitters. Their ability to withstand moisture should find them widely used in battery receivers and marine equipment, but since readers will be generally interested in their application to receivers we will consider their advantages in a typical dual-wave receiver.

Since in normal resonance circuits the voltage induced in the secondary is multiplied by the Q factor at resonance, it will be apparent that the P.V.C. coils will present some advantage in the matter of sensitivity apart from the improvement in selectivity. If we assume the Q value of 250 for the P.V.C. coil and 210 for the bakelite former coil, we can calculate the approximate stage gain from the following relation.

Stage gain $= g_m K R_D \sqrt{L_1/L_2}$.

g_m = mutual conductance of tube.

$K = \sqrt{M/L_1L_2}$ = coupling factor.

$R_D = 2\pi f L_2 Q_2$ = dynamic resistance of secondary.

L_1 = primary inductance.

L_2 = secondary inductance.

Suppose we take a typical R.F. inter-stage coil having the following values:—

Primary inductance (L_1) = .78 μH.

Secondary inductance (L_2) = 1.7 μH.

Mutual inductance (M) = .58 μH.

K = .5 (approx.).

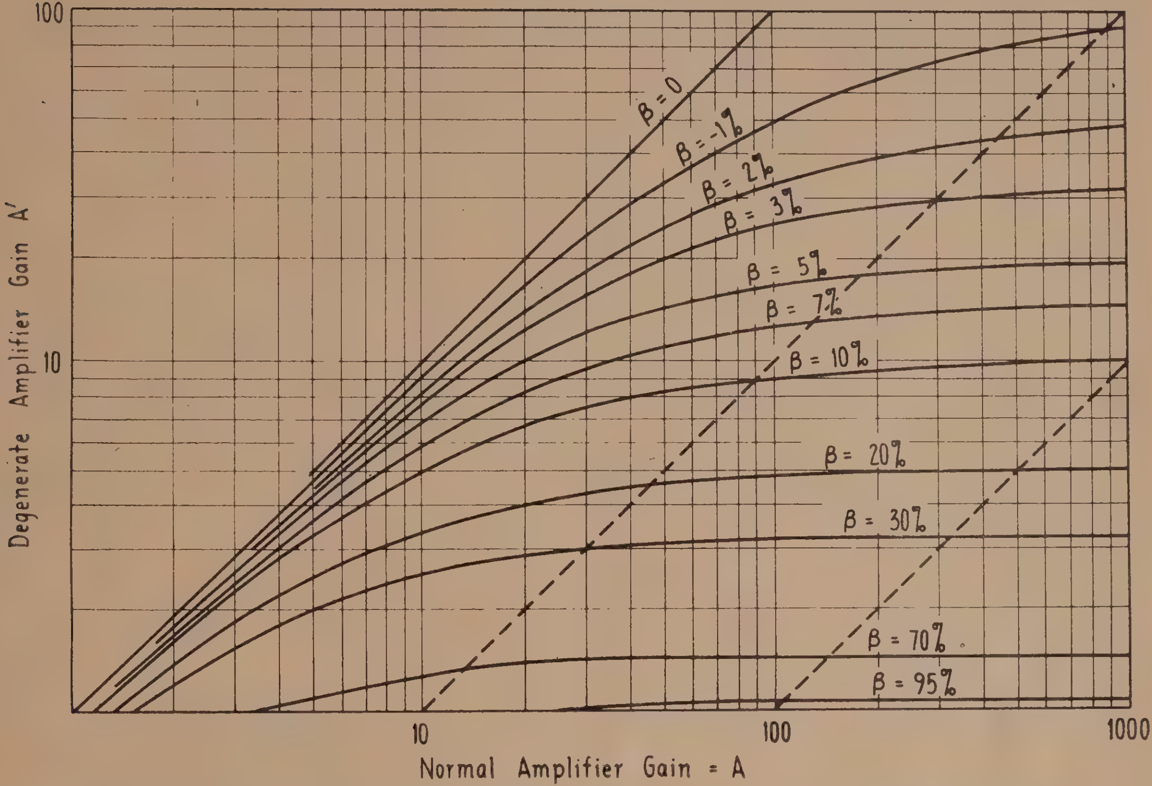
Assuming a 6SK7 tube having a mutual conductance of 2000 michromos, the calculated stage gain (R.F. grid to converter grid) is 27.2 for the P.V.C. coil and 22.8 for the bakelite former coil. This gives the P.V.C. coil a gain advantage of about 20 per cent. Since the gain of the antenna coil is difficult to calculate unless aerial constants are known, we can, for purposes of illustration, assume the gain of the bakelite coil to be 5, and by the addition of 20 per cent. obtain the figure 6 for the P.V.C. coils. This makes the total gain from the antenna to converter grid 114 in the case of bakelite coils and 163 for the P.V.C. coils—an increase of more than 40 per cent. or 3 db. Very much greater gain increases are possible if the comparison is made between P.V.C. coils and those wound on a half-inch diameter bakelite former.

IMAGE RATIO

Since any increase in Q factor means increased selectivity and less interference from image frequencies, the P.V.C. coils prsent considerable advantages. Image interference increases with frequency, and the rising Q factor of P.V.C. coils at high frequencies tends to offset the decrease in image ratio. The writer has handled domestic dual-wave receivers in which the image ratio at 10 megacycles was so low that some confusion existed as to the identity of image and fundamental frequencies.

(Concluded on page 48.)

DESIGN SHEET No. 5: THE PERFORMANCE OF AMPLIFIERS WITH NEGATIVE FEEDBACK



When negative feedback is applied to an amplifier, it is important to know how the gain will be affected by a proposed amount of feedback, or, alternatively, how much feedback is necessary to reduce the gain by a given amount. The reduction in gain caused by feedback is important for two main reasons. First, in designing an amplifier, it is necessary to know—at least, approximately—what input voltage is required for a stated output voltage or output power. If this is not known, it is possible to end with a design which has insufficient voltage amplification or with one which is uneconomical, and also unsatisfactory in other respects, because the overall amplification is greater than need be.

Even more important than this is the fact that the reduction of gain caused by feedback is an exact measure of the degree by which the feedback reduces the distortion present in the amplifier. For example, if the voltage gain of an amplifier is reduced to a tenth of its previous figure by the application of a certain amount of negative feedback, then the distortion with feedback applied is also one-tenth of its value before the application of feedback, but at the same output voltage or power. In many cases where negative feedback is applied over the output stage only of an amplifier, the figures are available from the valve data books for the percentage distortion at stated power levels. Sometimes the conditions are arranged so that the quoted figure for the power output is realized at a distortion level of 10 per cent. total. In this case, a reduction in gain by a factor of ten times would cause a similar reduction in distortion, and, if the other conditions specified in the data are adhered to, the distortion after the feedback has been applied would be 1 per cent.

Negative Feedback Formula

The basic formula which relates the three important factors governing the gain of negative feedback amplifiers is quite a simple one, and it takes comparatively little working out. However, it is often convenient to have a simple chart on which the answer to a particular problem can be read in a matter of seconds, and the accompanying graph is such a chart. The formula referred to is:

$$A/A' = (1 - \beta A) \quad . \quad . \quad . \quad (1)$$

where A is the voltage amplification without the feedback.

A′ is the voltage amplification with feedback applied, and β is the fraction of the output voltage fed back to the input.

This formula is completely general. It applies to feedback over any number of stages, and is equally true for positive or negative feedback. If the feedback is negative, then β is negative, and the formula becomes— $A/A' = (1 + \beta A)$.

If the feedback is positive, or regenerative, then the signs in equation (1) remain unchanged.

Substitution of trial values in these equations will show that they agree with practical experience. For example, if β is positive, the gain with feedback is **greater** than without feedback—a well-known fact of regeneration or positive feedback—and if β is negative, A' is less than A. This is the case under discussion in this Design Sheet, but the reverse case has been mentioned for the sake of completeness.

Using the Chart

It can be seen from the formulae above that the gain of an amplifier after feedback has been applied depends not only on β, the percentage of output voltage fed back, but on A, the gain without feedback. Thus, an amplifier whose gain without feedback is very high needs only a small percentage of feedback in order to reduce the gain by a given amount, whereas a low-gain amplifier needs a much larger percentage in order to reduce the gain by the same amount. This is clearly shown by the chart. The vertical axis gives the gain with feedback (A' in the formula), while the horizontal axis gives A, the gain without feedback. Each curve relates these two quantities for a stated percentage feedback. If any two of three quantities are known, the chart enables the third to be found. The examples given below illustrate how the chart is used.

Example 1:

"An amplifier has a voltage gain of 200 times without feedback. If 2 per cent. of the output voltage is fed back to the input so that the direction of feedback is negative, what will the gain of the amplifier be?"

Entering the chart at $A = 200$, we travel vertically until we reach the curve labelled $\beta = 2$ per cent. At the point of interception, we travel horizontally to the vertical axis, where we read off the new gain $A' = 40$.

Example 2:

"An amplifier stage is required to have a gain after feedback is applied of $A' = 10$. The valve handbook shows that the circuit decided upon has a gain A without feedback of 35 times. What value of, or, in other words, what fraction of the output voltage must be fed back to the input for the gain without feedback to have the required value of 10?"

Entering the chart from the horizontal axis at the value of 35 and travelling vertically until we reach the horizontal line representing the gain with feedback of 10, we find that these two lines on the curve equal 0.07. This figure is therefore the required answer.

Selecting Circuit Values

The chart does not indicate how the required value of β is to be obtained. There are a large number of circuits which may be used in order to apply negative feedback to a given amplifier. A representative selection of suitable ones is to be found in the "Radiotron Designers' Handbook," chapter 6.

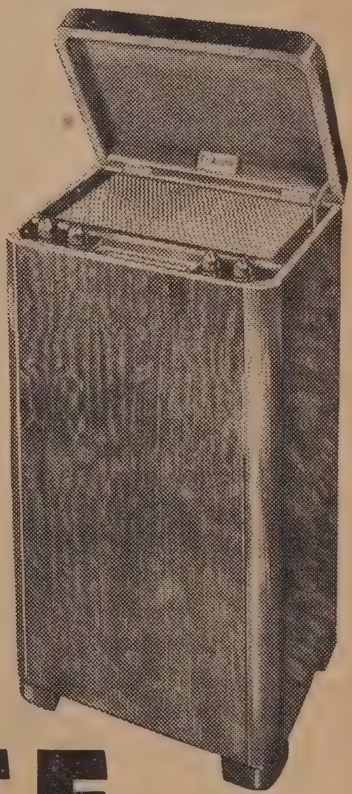
Several circuits are given for the application of feedback round a single amplifier stage, and one is given for a feedback over three stages of an amplifier, the output stage of which uses push-pull 6L6's. Two other arrangements which are commonly used with a push-pull output stage are to be found in an article entitled "Some Tested Circuits for 807's as Audio Amplifiers," which appeared in "Radio and Electronics" in September, 1948. In almost all such arrangements, whether single-ended or push-pull, the feedback voltage is applied through a network consisting solely of resistors. In cases where a blocking condenser is used in order to prevent the H.T. voltage from being applied to a grid circuit along with the alternating signal voltage, it is necessary to ensure that the blocking condenser is large enough for the low-frequency response of the feedback network to be very little attenuated. If low-frequency attenuation is present in the feedback network, the result will often be a low-frequency oscillation, since the drop in response of the feedback network causes the amplifier to have a much higher gain at extreme low frequencies than in the remainder of the audible range.

In many cases the value of β is simply determined by the voltage dividing action of two resistors which make up the feedback chain. In other cases, however, the calculation of the resistor values is quite difficult, because of relatively unknown degrees of shunting, produced on the feedback network by the plate resistance of a preceding valve. The cases described in the "Radiotron Designers' Handbook" give simple formulae by means of which the values of the resistance concerned may be chosen in order to give a pre-determined value of β. The most useful feature of the chart is that it enables some idea to be gained of the constants required in the feedback network, for, if the value of β is not known, one has to rely on experiment in order to arrive at suitable values. Also, in many cases where the value of β is easily calculated from the circuit values it is very helpful to be able to find out quickly what the effect will be of a certain percentage of feedback applied to a given amplifier, or to a particular amplifying stage whose gain without feedback is already known.

Brilliant NEW Design!

The Incomparable ULTIMATE *'Challen'*

NEW ZEALAND'S *FIRST* RADIO with **PIANO ACOUSTIC CABINET!**



ULTIMATE proudly announces a really unique achievement — the first radio with a cabinet designed on the basis of piano construction.

A highly efficient 5-valve broadcast chassis is housed in this special cabinet which features the principles of "tone projection" and "vibration deflection." The result is a superb tone of remarkable natural quality. The cabinet is dignified and beautifully finished . . . the whole is a radio you will be really proud to own.

The last word in Radio—

ULTIMATE

Manufactured by: RADIO (1936) LTD., P.O. Box 1166, Auckland

Wherever there's
PHI

LAMPS FOR GENERAL A

PHILIPS DOMESTIC LAMPS

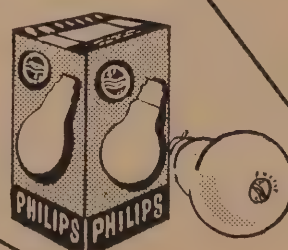
With a reputation built on quality, PHILIPS LAMPS are made in New Zealand to the world's highest standards of efficiency, and the salesman who handles this line operates with a background of confidence . . . he is selling not only lamps of unimpeachable quality but better lighting. PHILIPS Coiled Coil Lamps are as much as 20 per cent. more efficient than Single-Coil Filament Lamps.

PHILIPS NEON LAMPS

Nowadays, Neon Lamps are widely used because they offer certain exclusive advantages of gas-discharge lamps. One important advantage is the low current consumption, making them ideal for continuously burning indicator lamps, night lights, etc. Factories and workshops have made many uses of these lamps, particularly for indicating purposes.

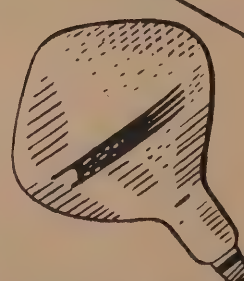
PHILIPS PROJEC

PHILIPS s
lamps, ciner
film and ho
lamps and
lamps, all o
to meet th
quiremen
their sp
purposes.
voltages,
tages, anc
for every
of proj
equipmen



PHILIPS SPECIAL-REFLECTOR LAMPS

In the series of special lamps produced are the Cornalux and Attralux spotlights, Altrilux floodlights, and Comptalux de Luxe glow lamps. Mention must also be made of the famous Philips Colorenta, Colorentina, and Philinea lamps, these latter being specially designed for the lighting of the home. Also in this special series are the Philips coloured Festoon Lighting Sets for party and dinner-table decoration.



LIGHTING S

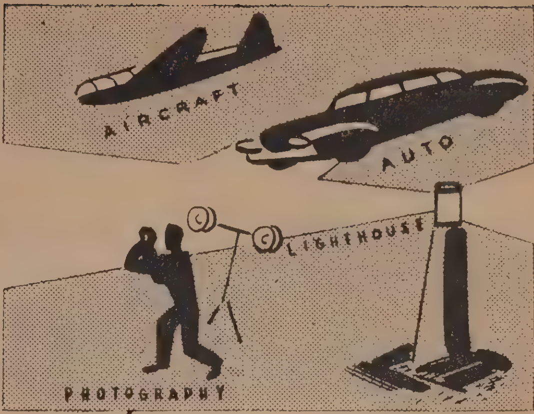
For tech
on all ligh
sult the Light
the Distributing
TURNBULL
Auckland, We
Dunedin, Ham

PHILIPS ELECTRICAL INDUST

AUCKLAND WELLINGTON

ighting there's

LIPS



SPECIALISED PURPOSES

TUBULAR
ON LAMPS

Tubular film
mps for normal
inema, exciter
icro-projection
m designed
rticular re-

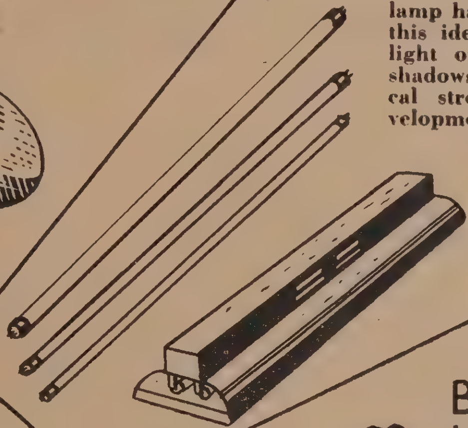
PHILIPS PHOTO-LAMPS

With photography playing such an important part in our daily lives, Philips have produced many photo lamps. Amongst others there are the Argaphoto, Photolita, and the Photomirenta for the professional photographer, giving diffused light and soft shadows.

PHILIPS

PHILIPS FLUORESCENT LAMPS

Obviously, the ideal source of light would be that in which the total energy supplied is converted into light without any loss in the form of heat. The Philips fluorescent lamp has been produced to as near this ideal as possible, giving high light output, great durability, no shadows and reflections, mechanical strength, and little heat development.



PHILIPS BLENDED LIGHT LAMPS

One of the most versatile lamps produced, the blended light lamps are medium-sized light units. Extremely suitable for interior and exterior lighting, creating a daylight effect by employing mercury light and incandescent light in a blending ratio.

RVICE BUREAU

l information
problems con-
Service Bureau of
nts for Philips Lamps

JONES LTD.

gton, Christchurch,
n, Palmerston Nth.

RIES OF NEW ZEALAND LTD.

CHRISTCHURCH DUNEDIN

PULSE MODULATION AND ALL THAT

It has recently been announced that the amateur band which covers 420 to 450 mc/sec. is available(as well as for the more conventional types of emission) for the use of pulse modulation. To some amateur transmitters, this will open up a considerable field for experiment with new and interesting circuits, but those who have not had any experience of pulse techniques through radar or other war-time devices may well be excused for asking, "So what?" or words to that effect. In more technical terms, this question amounts to several, such as "Has pulse modulation anything to offer the amateur that he cannot get from amplitude or frequency modulation?" or "It's all very well for those who want to build a radar set to use pulses, but why should we bother our heads about it when we haven't yet digested all this stuff about N.F.M. and S.S.S.C.?" Or, again, it might be asked, "Supposing that pulses **can** be used for communication purposes, as we have read in various overseas journals, why aren't we allowed to use them on a reasonably low frequency?" and "Surely it is difficult enough to get going on 420 mc/sec. without adding weird modulation circuits into the bargain. And, besides, what good will it do us, if any?"

The purpose of this article is to try to answer some of these questions, and perhaps some others as well.

Reasons for Using Pulse Modulation

First of all, let us look at some modern equipment, and see if we can tell why pulse technique is employed, and for what purposes.

The most obvious case is that of radar, which uses pulse transmission in most of its manifestations. Unfortunately, radar is not very much to the point in this argument, for the simple reason that pulses are used in it as a matter of principle. That is to say, with one exception, which is more or less obsolete, the principle of radar dictates that transmission be in short pulses, so that there is no real alternative to pulse modulation for this purpose. (The exception referred to is the C.W. radar principle, which depends on the comparison of **phase** of the transmitted oscillation with that of the reflected energy from the target. Except for radio altimeters, which work on this principle, the C.W. radar system is extinct.)

Another use for pulses is found in some British army equipment, designed for sending up to 12 messages (as voice signals) on the one R.F. carrier. In this system, the audio frequencies for each channel are caused to modulate the **length** of a train of pulses, at a supersonic frequency. There is thus one train of pulses for each channel. Now, it is possible, by means of comparatively simple circuits, to combine the 12 sets of pulses at the transmitting end and to separate them at the receiving end, in such a way that all twelve sets modulate the R.F. carrier simultaneously, but without losing their separate identity. Thus, at the receiving end of the system, it is possible to sort out any or all of the 12 trains of pulses, each of which carries one voice signal.

Pulse modulation has not yet been so applied, but it is perfectly feasible as a competitor to F.M. in the high-fidelity V.H.F. broadcasting field. Like F.M., it is characterized by a wide range of side-frequencies, and can therefore not be used on the crowded lower frequencies.

The above two applications indicate two important features of pulse-modulated waves. First, that multiple channels can be obtained on the one R.F. carrier frequency, the several messages being sorted out by means of their timing with respect to the others. Secondly, that by means of pulses it is possible to achieve a high signal-to-noise ratio at the receiver.

In the development of radar, the pulse system was, in fact, the only thing that made radar itself a completely practicable proposition, and the advantage given by pulses in radar systems can be made use of elsewhere, too. The point we are trying to make is this: that, in order to generate the enormous transmitted power outputs that were required AT VERY HIGH FREQUENCIES in order that the range of the system should be great enough, pulse modulation was essential, apart from its fundamental necessity for other quite different reasons. How it came about was this. In order that low-flying aircraft could be detected, it was necessary to work the radar systems on as high a frequency as possible, and in 1937, when the R.A.F. was really "getting cracking" on providing the coastal defence chain, it was not possible, outside the laboratory, to produce hundreds of kilowatts of power above 30 mc/sec. in any way that would have made a C.W. system economic. But by using pulses, which were desirable anyway, as we have said, it was possible to produce hundreds of kilowatts at frequencies where even one kilowatt of C.W. was a very different achievement. This gives a very good clue as to how amateur transmitters can make use of pulse technique.

For example, it is a comparatively simple matter to generate a few watts of R.F. at 420 to 450 mc/sec. Under favourable conditions, this is all that is required for simple line-of-sight communication. But if one wants to try more distant contacts on a frequency such as this, only one thing will help much, and that is power output, and plenty of it. Even for short-range communication on this frequency, pulse modulation could have important advantages, as any method of increasing the effective power of the transmitter must do.

How can Pulse Transmission Increase the Effective Power?

As Dr. Joad would say, it all depends what you mean by "effective power." Suppose, for instance, that we have a certain transmitter which has an output of 100 watts on C.W. and that we are going to pulse-modulate it without making any other changes. All that the pulse modulation really does is to key the transmitter on and off, just as does the manual key, but at a much greater rate. For example, the pulses might occur at a rate of 10 kc/sec. and the transmitter might be keyed on for only a tenth of the time and off for nine-tenths of the time. Thus, the AVERAGE power transmitted has been reduced to only a tenth of the power radiated when the transmitter is operating with the key down, simply because the "key" is down for only a tenth of the time. This seems to represent a loss rather than a gain, but a little consideration shows that the reverse is true. If the 100 watts C.W. was sufficient for reliable communication to a given place, then the 10 watts average power will still put in just as strong

a signal as before, because **during the pulses** the power output is still 100 watts. The pulses are therefore received just as well as was the C.W., and yet the average transmitted power has been reduced by a factor of 1/10. All that is necessary in order to take advantage of the power economy made possible in this way is to find some way of making the pulses themselves carry the intelligence previously transmitted in the dots and dashes of the code. We will leave this aspect of the matter for a moment, and pursue the pulse-power relationships a little farther.

First of all, there is no reason why the power economy can not be increased by making the pulses shorter. For instance, if each pulse lasts for only one-twentieth of the time of the pulse cycle, the average power will have been reduced to only 5 watts, while the power in the pulses still remains at 100 watts.

Basically, there is no reason why the same process should not be carried even farther. Just stop for a minute to realize what this means. Supposing that we were allowed to use pulse modulation on the lower-frequency bands. The argument we have been pursuing shows that, with an average power of 5 watts or even less, we could get just as reliable communication as with 100 watts of C.W. This represents a considerable saving of power. For example, it would be quite possible, other things being equal, to run the equivalent of a C.W. 100 watts from dry batteries!

There is another way in which the pulse system can be used, and this will commend itself to amateurs. Supposing that we are now pulse-modulating our original transmitter, at a duty cycle of 1/10. That is to say, the "on" period of the transmitter is 1/10 of the total time. If the plate voltage of the final stage has not been changed, we will find that the plate current, as read by the meter, has dropped to 1/10 of its key-down C.W. value. This is just asking for steps to be taken to bring the final plate current back to where it was before, either by loading it more heavily, increasing the plate voltage, or both. In other words, if there were no other limitations besides plate dissipation, we would be able to get a power output during the "on" periods of ten times the C.W. value without exceeding the ratings of the final amplifier. Of course, this is a vast over-simplification of the case, but it illustrates the possibilities. At least it is plain that if we are pulsing our final amplifier, it must be possible to get a considerable increase of power output during the pulse compared with the C.W. power output. Thus, if we assume that we can increase the pulse input to three times the C..W value and still keep well within the valve's dissipation ratings, we will have increased our signal at the receiver by 10 db., while still using the same final stage and power supply.

In radar transmission, the duty cycle is usually extremely small. For instance, with pulse lengths measured in fractions of a micro-second, it is not out of the way for the pulse power to be in the region of 500 kilowatts—and this is the effective transmitted power for practical purposes—while at the same time the average power input to the final amplifier is only 100 watts or so! Of course, gains of this nature can not be realized in normal communication practice, but the radar case amply illustrates the possibilities.

As for questions such as just how much effective gain can be realized with the small tubes used by amateurs, and how the necessary pulses are generated, and how they are made to modulate the R.F. carrier, and how they are made to carry intelligence, these will have to be left for a future article.

ELECTRONIC MUSICAL INSTRUMENTS

By **C. R. LESLIE (Member of the Electronic Music Group)**

In previous articles on electronic music, which appeared in our July and September issues, 1947, a brief general outline was given dealing with various lines of development and the importance of waveform in instrument design. In these articles we discuss the more practical aspects in the evolution of simple melodic or "single voice" types.

PART I

Introduction

Those readers who have read our earlier articles will appreciate that there are many lines of approach to the subject, and perhaps may be rather more appalled than inspired by the great wealth of possibilities and the apparent complexity of the apparatus required. It is not given to many of us to have access to precision mechanical tools even if we have the necessary skill and experience to operate them. Undoubtedly, electro-mechanical systems are convenient for the design of complex instruments, but it is absolutely essential that the mechanical components be of the precision standard as recognized to-day.

But if we by-pass the complex instruments we may still derive much pleasure and interest in the development of single-voice instruments of various types, such as the individual instruments that go to make up an orchestra. Fortunately, these do not call for much mechanical complexity as they may be evolved through purely thermionic media and thus be within the scope of any amateur enthusiast. In these articles we discuss some of the practical aspects involved so that readers may start work on their own account with any particular instrument they may fancy. Research work in this field is going ahead in Britain to-day in spite of the difficult conditions prevailing and we hope that Dominion readers will be sufficiently interested to take up this quite fascinating branch of "radio" engineering also.

General

First of all, let us see, in a very general way, what is involved in the design of a conventional melodic instrument of any type. It will comprise two main factors, namely (1) the sustained or steady note tone colour (timbre), and (2) the acoustic result of "attack" or method of playing—the combination of the two gives the recognizable characteristic of the instrument. The sustained note waveform will be of a definite shape as it will contain a fundamental plus certain superimposed harmonics of varying but definite amplitudes. If we can design an oscillator to reproduce this waveform we have only to amplify it sufficiently to operate a loud-speaker to obtain the correct sustained note character of the instrument. The "attack" has then to be added to complete the work. The "attack" effect usually consists of initial and terminal transient frequencies of an accidental nature, that is, they need not have any harmonic relationship with the fundamental of the note played. An acceptable compromise can be achieved by the sudden application of complex frequencies to cover a range of sustained notes.

The whole set-up is then, (1) a power source which can follow normal A.C. mains power pack methods, (2) the waveform generator for the full range of pitch and "attack" frequencies, and (3) the final amplification for loud-speaker operation and the control systems. It will be seen from this that the crux of the matter lies in the waveform generator and the mechanical element of the control system, the rest of the equipment being on quite normal lines, although, as pointed out in the earlier articles, advantage can be taken of the speaker mounting and cabinet resonance to help out with the final acoustic quality.

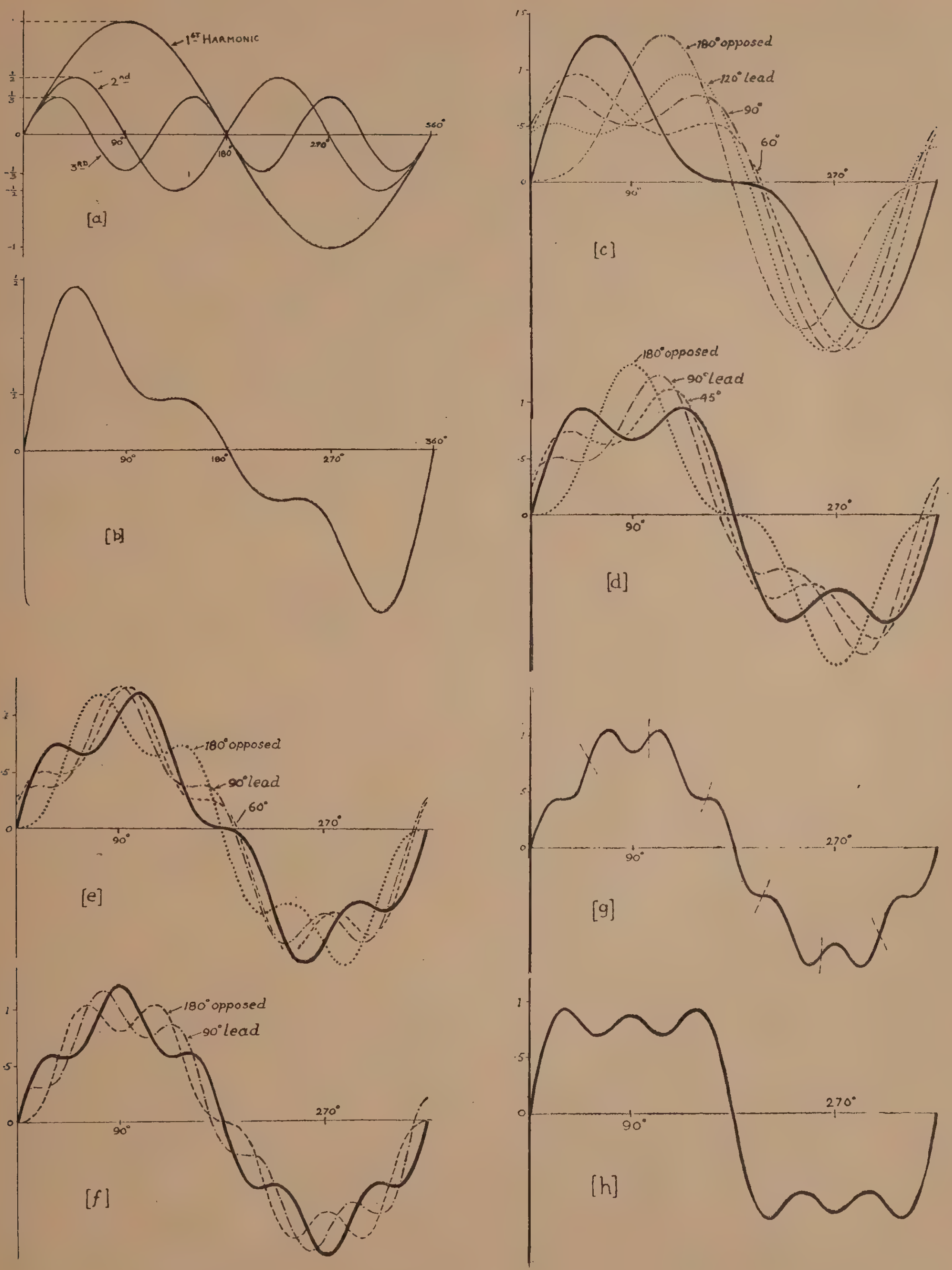
Effect of Harmonics on Waveform

The most direct method of attacking the problem is to make use of an oscilloscope. If the correct waveform for any particular tone colour is known, and if an approximate knowledge of the harmonic content is also known we immediately possess a working basis for circuit design, the oscilloscope image then offers the readiest means of portraying our waveform output, and/or the effect of any modifications carried out. The sustained note waveform is obviously the first step to receive attention and when a satisfactory compromise has been achieved it is time enough to deal with the superimposed "attack" frequencies.

The visual estimation of harmonic content is by no means easy, quite apart from the additional alteration caused by phase difference. But matters are simplified somewhat if we have a basic knowledge of the subject, and for this purpose the curves of Fig. 1 may prove useful. At (*a*) we show the first three harmonics (i.e., the fundamental and 2nd and 3rd harmonics) in phase and as separate sine waves in their natural amplitudes, while (*b*) shows the result of mixing them. At (*c*) we have the 1st and 2nd harmonics in phase (thick line) and the effects of different degrees of phase shifts (broken lines), while (*d*), (*e*) and (*f*) are similar curves for the 1st and 3rd, 1st and 4th, and 1st and 5th harmonics respectively. Orders above this mainly become apparent as an increased ripple on the fundamental as shown at (*g*), which represents the 1st and 7th harmonics in phase. It will be seen that in simple curves of this nature the order of the harmonic can be counted as shown by the spaces between the short cross lines.

The curve of (*h*)—1st, 3rd, and 5th harmonics—is important, as it shows that a series of odd harmonics approximates to a square wave which can be readily achieved by the well known "limiting" action or the top and bottom cutting of a sine wave. So that if our selected tone colour is rich in odd harmonics we can start right away with a "limited" sine wave and later stress particular orders by the use of tuned "formant" circuits.

Space does not permit a detailed discussion on this subject, and readers can easily prepare any desired curve for themselves by the use of squared paper, the sine tables and a little patience, remembering that the natural amplitude of any harmonic is proportional to its order as shown at (*a*), so that due allowance can be made for any specially stressed harmonic orders. This was exemplified in Fig. 5 of our September article and may be referred to. It will suffice here if we point out certain facts that emerge from a study of the curves in Fig. 1 as follows:—(1) Waveforms due to harmonics in phase with the fundamental are symmetrical in the two half-



1ST HARMONIC
2nd
3RD
360°
90°
180°
270°
[a]
[b]
180° opposed
120° lead
90°
60°
[c]
180° opposed
90° lead
45°
[d]
180° opposed
90° lead
60°
[e]
[f]
[g]
[h]

Fig. 1.

cycles; (2) even harmonics out of phase cause asymmetry between the two half-cycles, while (3) odd harmonics out of phase retain their symmetry, and (4) where single harmonics are concerned their order can be ascertained by counting. Fig. 1 (*c*) shows that the 2nd harmonic in phase tends to increase the crest amplitude of the curve (the fundamental has been allotted an arbitrary peak of one unit), while (*d*) shows the 3rd harmonic in phase has a damping effect. Fig. 1 (*c*) further shows that leading phase angles of the 2nd harmonic damps the first half-cycle while amplifying the second, while (*d*) shows that leading phase angles for the 3rd harmonic tends to amplify the peaks in both half-cycles up to a maximum of 180° opposed. The 4th and 5th harmonics reverse the effects of (*c*) and (*d*) respectively—the 6th and 7th harmonics will revert to the action of the 2nd and 3rd and so on all along the line.

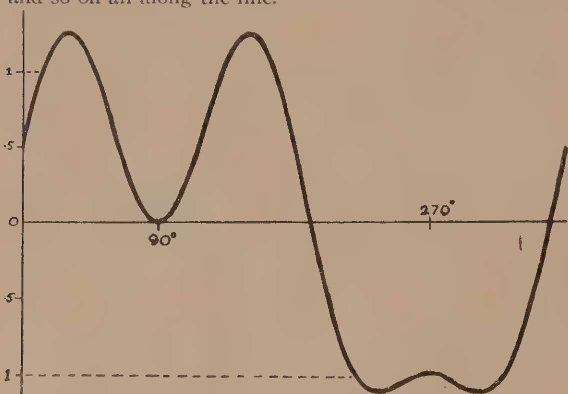


Fig. 2.

Let us see how this works out by considering the curve of Fig. 2 which we are to analyse. Firstly, the two half-cycles are asymmetrical and hence we may deduce the presence of an even harmonic out of phase and since the amplifying effect resides in the second half-cycle we assume a 2nd or 6th with a leading angle or else a 4th with a lagging angle, the 6th order is immediately eliminated by the small ripple content. Then the severe damping of the first half-cycle and a lesser damping of the second suggests the presence of an odd harmonic as well, and this enables us to reject the above 4th harmonic hypothesis on account of low ripple content, and so assume a 2nd and 3rd only. Now the curve starts at 0.5 units, which represents the peak amplitude of an unstressed 2nd harmonic and hence we may assume a leading angle of 90°, and from Fig. 1 (*c*) we see that the maximum damping occurs at 90°. But (*d*) also shows maximum damping at 90° and hence at this point the effects are additive. From the curve, the additional damping due to the 3rd harmonic is 0.5 units, but as the natural peak value is 0.33, it follows that this harmonic must be stressed some 50 per cent. The full analysis now becomes a fundamental sine wave on which is superimposed an unstressed 2nd harmonic with a leading angle of 90° plus a 50 per cent stressed 3rd harmonic in phase with the fundamental. The correctness of this result can be proved by plotting a corresponding graph.

Although not essential, a basic understanding of waveform is of great practical assistance and should materially reduce the number of trial and error experiments, and it is hoped that the foregoing remarks will help in this direction. We conclude this section with the algebraical formulae for certain definite wave shapes:—

Square Wave. $Y = 4/\pi\, E(\cos X - 1/3 \cos 3X + 1/5 \cos 5X - 1/7 \cos 7X + \ldots)$

Triangular. $Y = 8/\pi^2\, E(\cos X + 1/9 \cos 3X + 1/25 \cos 5X + 1/49 \cos 7X + \ldots)$

Saw Tooth. $Y = 2/\pi\, E(\sin X - 1/2 \sin 2X + 1/3 \sin 3X - 1/4 \sin 4X + \ldots)$

It will be seen that the square wave comprises a series of odd harmonics, where E is the peak voltage of the fundamental. The triangular wave is a "square wave" with the sides sloped so that there are no flats. The saw tooth comprises a series of odd and even harmonics. The manner in which these formulae are linked with oscillator design will be shown later.

Use of Spectrum Diagrams

The value of spectrum diagrams as an aid to circuit design was touched upon in our September, 1947, issue (Figs. 5 and 6) in that the constructor obtained evidence of the order and amplitude of the harmonic content. At the same time it was pointed out that strict adherence was not of major importance as such data varied from instrument to instrument of the same type on account of structural differences. A "family resemblance" is all that is required in the initial stages as the final quality will be judged by ear.

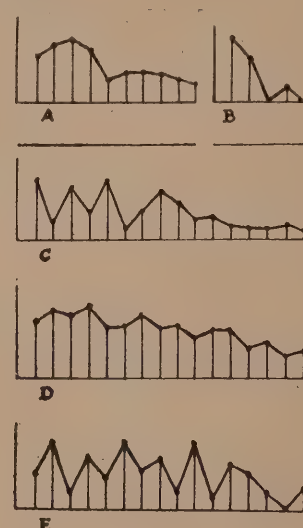


Fig. 3.

In Fig. 3 we show typical spectrum diagrams of some orchestral instruments—the harmonic order being along the X axis and the amplitude along the Y axis, the first vertical line in each case represents the amplitude of the fundamental or 1st harmonic. At (*a*) we have the diagram for a metal flute and may be compared with that for a wooden flute at (*b*). The harmonic increase of (*a*) provides the "metallic" tone. The clarinet at (*c*) shows stressed 3rd, 5th, 7th, 8th, and 9th harmonics—in practice we could eliminate (initially at least) the 8th harmonic and generate a near square wave and slightly suppress the fundamental on amplification. The trumpet at (*d*) shows a series of stressed odd and even harmonics which point to the use of a relaxation or saw tooth oscillator as a starting point. The bassoon at (*e*) is practically the reverse of the clarinet and we require a series of stressed even harmonics for which full wave rectification forms a suitable basis. Fig. 7 of the September issue gave the waveforms of similar instruments, and these may be compared with the above.

Practical Oscillator Considerations

We are now in a position to consider the practical possibilities of oscillator systems in the light of the foregoing, but at the same time keeping a mental eye on the mechanical method of keying the "notes." Oscillators may be controlled by the variation of INDUCTANCE, CAPACITY or RESISTANCE or by a *combination of these factors*. Mechanically, inductances are most readily varied by the use of a variable iron core by movement in or out of the coil. Capacity variation is easiest with very small values, which fact rather points to the use of "B.F.O." systems. Resistance may be varied in many ways, the simplest being by contact keying along a wire-wound resistor—or we may use photo cells if such are available.

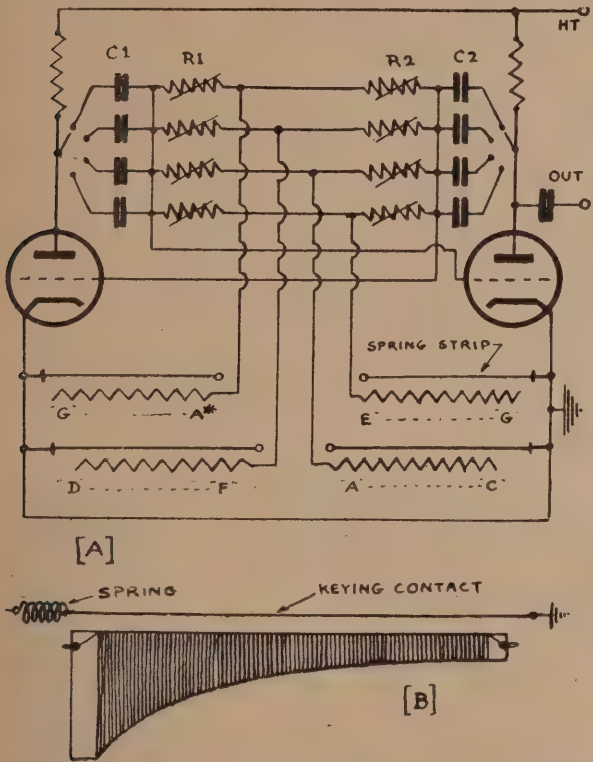


Fig. 4.

Oscillators may be designed to produce a great variety of waveforms, ranging from a pure sine wave to spaced square or triangular pulses and it is not possible to deal with them all here. We can, however, consider a few types that offer specially favourable characteristics such as simplicity of construction combined with ease of operation and stability.

Perhaps the most versatile and adaptable system is our old friend the "multivibrator" which must be familiar to all our readers, in its basic form at least. The waveform output from either anode is an exponential saw tooth and therefore rich in both odd and even harmonics. It operates very readily and can be maintained in a quiescent state until keyed, and the pitch range for any one condenser setting is reasonably wide. As is well known, the oscillation frequency is governed by the C.R. values for the two valves. If $F_0 = 1/2CR$, and if the values of C are fixed, the required values for R can be easily calculated for any desired musical note, keeping the capacity values low to avoid heavy charging currents. For instance, supposing we wish to find R for the note "B" (240 cs/sec.) and we make $C = 0.025\ \mu f.$, we rearrange the formula to read $R = 1/2F_0C$, or $R = 10^9/2F_0C$ (C being in Farads). Therefore, $R = 10^9/2 \times 240 \times 25$, from which R will be found to be 83,333.3 ohms.

Suppose we wish to design a "four-stringed" instrument with a pitch range from "G" (192 cs/sec.) to "G" (3,072 cs/sec.), and the four "open string" values being (1) "G" (192 cs/sec.), (2) "D" (288 cs/sec.), (3) "A" (426.67 cs/sec.), and (4) "E" (640 cs/sec.), we will find that for the 1st string from "G" (192) to "A♯" (921.73) if we make $C = 0.025\ \mu f.$, R will vary from 104,200 ohms to 21,700 ohms. For the 2nd string from

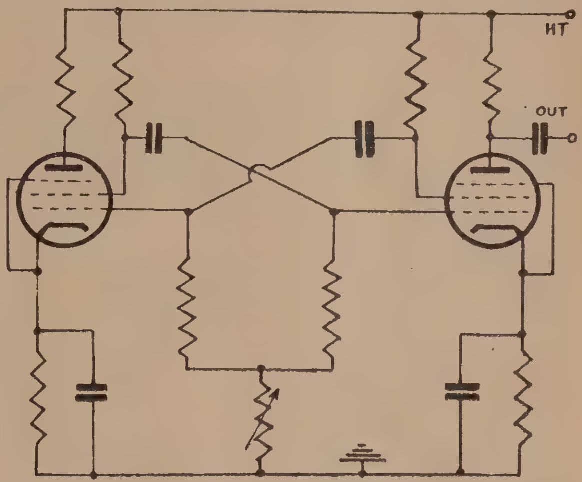


Fig. 5.

"D" (288) to "F" (1,365.33) with a condenser of 0.015 $\mu f.$, R will vary from 115,700 ohms to 24,420 ohms. The 3rd string from "A" (426.67) to "C" (2,048) with a 0.01 $\mu f.$ condenser, R will vary from 117,400 ohms to 24,420 ohms, and the top string from "E" (640) to "G" (3,072) with a condenser of 0.007 $\mu f.$, R will vary from 111,600 ohms to 23,250 ohms. The values for R for each string are therefore reasonably similar, which fact will simplify the windings. The former can be conveniently cut from ⅛" bakelite sheet, or the like, and the final shape (calculated from the resistance wire tables—nichrome wire is the most convenient to use) will be found to take a "logarithmic" curve as shown in Fig. 4 (*b*). Fig. 4 (*a*) gives a schematic of the general circuit set-up in which the condensers have been shown as "banked" for greater clarity. In practice it would be better to use four multivibrators, using double triodes. The keying is effected by means of the earthed metal strips tensioned over each variable grid-leak. It is also a convenience to use a "pot." as part of each grid-leak as an overriding pitch control—in the above case one of 25,000 or 50,000 ohms would be suitable. The output from the system is then passed through normal audio stages to feed a speaker.

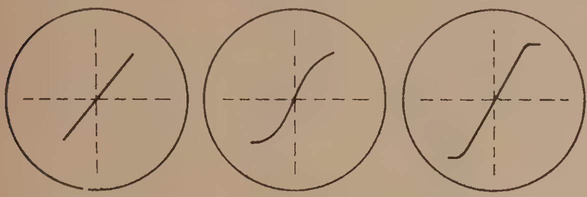
The multivibrator principle may be used for the generation of square waves by employing pentode valves as shown in Fig. 5. The circuit is particularly useful for the operation of relays or magnetic rotary switches because of the rapid make/break action and the pro-

(Concluded on page 48.)

A FIVE-INCH OSCILLOSCOPE

(Continued from page 14.)

distortion has started to creep in, it is much easier to use the straight line which results when there is no phase difference between the input and output voltages, than to use the ellipse that forms when phase-shift is present. There are also other advantages in so doing, because the frequency of zero phase-shift is always in the middle range of frequencies, where the performance is perhaps the most important.



(a) *(b)* *(c)*

Fig. 7.

Having made the appropriate connections, how is distortion observed? First of all we proceed as for the observation of phase-shift, and mark on the screen the position of the un-deflected spot, and preferably the axes also. These are drawn dotted in Fig. 7, which shows three representative patterns for the distortion test. Then we apply input voltage to the amplifier under test, and set the output power to a figure well within the alleged capabilities of the amplifier. At this, the test oscillator is tuned to the frequency of zero phase-shift, as shown by the pattern collapsing into a straight line. If the amplifier really is well within its capabilities, the resultant line really will be straight, indicating that no distortion is present. This state of affairs is shown in Fig. 7 (*a*). The slope of the line is of no consequence, as it is determined solely by the relative amplitudes of the deflection voltages. If the amplifier under test is a high-gain one, and a 'scope amplifier is not used to increase the voltage applied to the X plates, the line will be almost vertical. In fact, if the actual input and output voltages of the amplifier are applied to the plates of the C.R.T., the slope of the line is a measure of the voltage gain of the amplifier under test. This is quite a good method of measuring the gain of a single stage, as long as it is not too high for accurate measurement of the small input voltage. It is, of course, unnecessary to measure the output or input in volts, but only to measure the lengths of the X deflection (with the Y plate disconnected) and the Y deflection (with the X plate disconnected) and divide the output length by the input length.

However, this is by the way, as we are attempting to estimate when distortion arises. To do this, the input to the amplifier is gradually increased. At some point, the straight line ceases to be a straight line and becomes curved. The curvature represents distortion. Unfortunately, a very small curvature, and therefore a very low distortion, is difficult to see, but for comparative tests this is no disadvantage. For example, suppose we are investigating the behaviour of a simple amplifier consisting only of a pentode power amplifier, and that what we are trying to do is to see, experimentally, what the best value of cathode bias resistor is. The proper way to attack the problem is as follows.

The circuit is connected to the oscilloscope as before, and a trial value of cathode resistor inserted. The input is increased until the onset of non-linearity is judged to have commenced. At this point, the voltage output is measured, as the length of the vertical deflection. The next trial value of cathode resistor is placed in circuit, and the output voltage measured again, for the new point where departure from linearity is just noticeable. If this process is continued for a number of values of cathode resistor, it will readily be seen from the results whether the optimum value is within the range tried, or whether the trend is towards better results, or should be taken the other way. This method, it will be noted, depends not on measuring the actual amount of distortion present, but only on the ability of the operator to judge when the pattern is similar to the one initially chosen to represent the overload point. An exactly similar procedure can be carried out, for example, in finding out the best value of load impedance to use for an output valve. Admittedly, this information is usually available in the valve manuals, but not always, and certainly not for any operating conditions other than those recommended. For example, suppose it is necessary to use a 6V6 as the output stage of a receiver which is to be powered from a vibrator supply, which cannot give enough milliamps to enable the 6V6 to be run at full current. How are we to arrive at the proper operating conditions, supposing we have to limit the plate current to 25 ma.?

With a 'scope, this problem can easily be solved experimentally, much as was done in the case of the tube which had to have the best value of cathode resistor determined. First of all, we can reduce the screen volts to, say, 180 volts by means of a dropping resistor. This will mean that the screen has to be by-passed to earth by an electrolytic condenser, which is unusual for an output tube, but only because they are usually run with equal plate and screen voltages. A suitable dropping resistor and bias resistor are chosen by experiment so that the screen voltage and the required plate current are obtained. The final step is to find out (*a*) what load resistance will give the greatest undistorted power output, and (*b*) whether this power output is great enough for the purpose in hand. This is where the 'scope comes in. A choke of 20 or 30 henries is placed in the plate circuit of the valve, and a trial value of load resistance is placed in parallel with the choke. This places the load resistor at H.T. potential, but has the advantage that a large coupling condenser is not needed. The 'scope is connected across the input and output of the amplifier, as before, and the input is increased until distortion is just visible. Now, since we are interested in power output, we will have to measure the voltage across the load resistor, and work out the output power from the formula $P = E^2/R$, where P is the power output in watts, E is the R.M.S. output voltage across the load, and R is the value of the load resistor.

Thus, in this experiment, we have to go a little further than before, and actually measure the R.M.S. output voltage. This can be done quite easily, and we need not worry too much about high accuracy, because the object is mainly to obtain a comparative result, and in doing so, errors of measurement are largely cancelled out. All that has to be done is to calibrate the trace of the 'scope in terms of R.M.S. volts, for the vertical deflection. This can be done in this way. An A.C. voltage, of known value, is placed on the Y plate, and the length of the trace is measured. The known voltage can be, say, the output of a 6.3v. heater winding, and, with the aid of the multi-meter, the actual R.M.S. voltage can be measured at the same time. (It is best not to take the voltage on trust, as the actual voltage might be con-

siderably different from the nominal value.) Suppose, for example, the meter says that our winding is 6.2 volts. This gives a deflection on the screen, we find, of 0.4". This gives us a figure of 15.75 volts R.M.S. per inch of deflection. In order to measure any output voltage, all we have to do now is to measure the length of the trace in the vertical direction, in inches, and multiply this by 15.75.

Once the calibration has been done, there is no need to do it again throughout the experiment, and we can now proceed to choose a further trial value for the load resistor, and measure the power output again. After a few values have been used, it will be easy to see the approximate value of load resistor needed for maximum output at the distortion level that is automatically chosen by observing the pattern.

The above two examples have been given to show how a wide variety of experiments can be performed, using the same basic method, and the same connections to the 'scope from the test circuit.

The phase-shift picture can also be used to see whether anything untoward is happening in the amplifier. If spurious oscillations are taking place, they can very readily be spotted, as they will show up as a vertical deflection on the tube when no input voltage is applied to the amplifier. It is also an easy matter to see whether the amplifier goes into oscillation only at some particular output. If this is the case, the line will become spread out at some point, and "wiggles" may even appear, by means of which the approximate frequency of the oscillation can be estimated.

Figs. 7 (*b*) and (*c*) illustrate how the 'scope shows up the remarkable difference in performance between an amplifier without negative feedback, and the same amplifier with a large degree of feedback. In both figures, the output voltage is about the same, but in Fig. 7 (*b*), which shows the amplifier without feedback, it can be seen that advanced distortion has set in, as evinced by the curvature of the line. In Fig. 7 (*c*) distortion is also present, but it can be seen that the pattern is a very straight line for most of the way, after which it bends over very suddenly, and produces the horizontal tails, which show that the output voltage is no longer increasing at all as the input voltage is raised. It can be seen from these figures that the first amplifier must have had considerable distortion present, long before it reached the advanced stage illustrated in Fig. 7 (*b*). The feedback amplifier, on the other hand, is virtually distortionless until a very critical overload point is reached. This behaviour is very marked with amplifiers such as the Williamson circuit, and those described in a recent issue of *Radio and Electronics* for 807's as triodes and pentodes. With amplifiers not employing such a high degree of feedback, the overload behaviour is intermediate between the cases illustrated. This is yet another demonstration of the usefulness of the 'scope, without even a linear time-base. Without it, it would take several hours of plotting input/output curves laboriously by hand to arrive at the above results, which, once the 'scope has been connected up, take only a few minutes to obtain.

* * *

"RADIO AND ELECTRONICS"

Back and current numbers of "Radio and Electronics" may be obtained from—

Te Aro Book Depot, Courtenay Place, Wellington.
S.O.S. Radio Service Ltd., Queen St., Auckland.
Tricity House, 209 Manchester St., Christchurch.
Ken's Newsagency, 133–135 Stuart St., Dunedin.

A PANORAMIC ADAPTOR

(Continued from page 11.)

average grid current, as well as the amount by which the grid goes positive, is very small indeed. Experience has shown that small triodes and pentodes will operate almost indefinitely under these conditions. It is only for a few cycles after the switching on that the actual grid voltage and current reach values that are at all high. There is thus no need to worry about whether the unfortunate 6SJ7 can stand the gaff.

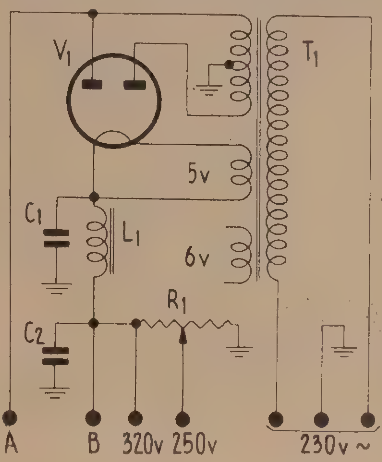
The 6AC7, V_6, is used to linearise the saw-tooth voltage from the plate of V_5, and also to provide a low-impedance output for the time-base circuit as a whole. This enables the leads to V_2 and V_8 to be made as long as desired without difficulty, so that these two valves need not be placed on the chassis close to V_6. In the original model, V_6 was at the other end of the chassis from both V_2 and V_8, and using the cathode-follower linearising valve prevented any loss of linearity in the saw-tooth that would otherwise have occurred through shunt-capacity in the wiring. The low output impedance also effectively prevents the long leads from picking up undesired hum. Both R_{22} and R_{24} are pre-set controls, and are therefore not mounted on the front panel. R_{22} is placed on the chassis close to V_2, and *not* near V_6 as might be expected. The same applies to R_{24}, which is mounted as near as possible to V_8. The reason is that as soon as the condensers C_{18} and C_{24} are connected in the output lead, the impedance on their far side is no longer low, being roughly equal to the value of the resistors connected from the output side of the condenser to earth. Thus, while the impedance on the V_6 side of C_{28} is very low, that on the V_8 side of the condenser is 500k., the value of the input potentiometer. Thus, if the condenser is placed at the V_8 end of the line, the low-impedance output of the cathode-follower is lost as far as its practical advantages are concerned. The same argument applies to the placement of C_{22}.

R_{22} controls the amount of saw-tooth voltage fed to the grid of V_2, the reactance modulator. It therefore controls in turn the degree of frequency-modulation of the 6K8's oscillator. It is thus the sweep control. If it is turned right off, no saw-tooth at all is fed to the modulator, and the frequency of the oscillator is fixed, at 365 kc/sec. If maximum voltage is fed from V_6, the oscillator frequency sweeps from about 315 to 415 kc/sec., a range of plus and minus 50 kc/sec. Since there is little point in bringing this control to the front panel, it is placed on the chassis, and after the adaptor has been set up, and the face of the tube calibrated in kc/sec., it is left untouched.

The potentiometer R_{24} varies the amount of saw-tooth voltage fed to V_8, which is merely an audio amplifier, with the purpose of bringing the saw-tooth to a great enough amplitude to deflect the trace right across the face of the cathode ray tube. Since this will normally be set so that the full face of the tube is used, by making the horizontal trace sweep right from one side to the other, there is no necessity for R_{24} either to be anything but pre-set.

V_9, the other half of the 6N7 amplifier tube, is used simply to ampify the audio signal voltages from the second detector, so that full deflection in the vertical direction can be obtained. It will be noticed that there is no gain control in the audio end of the circuit, and that the R.F. gain control, R_2, is the sole means of varying the height of the responses on the C.R.T. The reason for this has been partly explained above, but there is also another good reason for this method of control. It is that a true picture of the response curve of the 100 kc/sec. I.F. amplifier will not be obtained if it is possible for the mixer and/or I.F. stages to be overloaded. The R.F. gain control prevents this from happening, in the same way that in audio amplifiers the best place for the gain control is ahead of the whole amplifier, in order to prevent overloading of the first amplifying stage.

V_7 is a voltage regulator tube, which supplies 150 volts to the oscillator plate, and the screen-grids of the 6K8 and the reactance tube, V_2. This helps to stabilize the performance of the oscillator, and is necessary because the L/C ratio in the oscillator tuned circuit has to be too high for good frequency stability, on account of the difficulty of realizing enough frequency sweep when the capacity in the circuit is too high.



T_1, Power Transformer, 350 v. a side, 80 ma.
L_1, Smoothing Choke, 80 ma.
C_1, C_2, each 16 μf. 450v. Electros in series, with 250 k. Balancing resistors in parallel with each condenser.
R_1, 25 k. 25-watt wire - wound, with tap.
V_1, 80 or 5Y3-G.

Fig. 2.—Power supply for the unit.

Constructional Details

The cover picture on our last issue did not really do justice to the appearance of the unit, but at least showed the main features of the lay-out. The cathode ray tube is mounted in a square box, 3½" x 3½" x 10¾". This is made from steel at least 16 gauge in thickness, and is to help prevent electro-magnetic hum from broadening the spot. The box is mounted in the exact centre of a chassis 12" deep by 10½" wide, by 3". This leaves a small amount of room at the back for the Amphenol seven-pin socket which holds the C.R.T., and which is mounted in the centre of the back of the C.R.T. box. It also leaves two spaces down each side of the chassis, in which the valves can be mounted. Looking from the back, which is the view illustrated in the photograph, we have on the right the signal circuits, which progress from the front of the chassis to the back, exactly following the progression of the circuit. Right at the front, therefore, is the 465 kc/sec. transformer, and following the line-up comes the 6K8, a 100 kc/sec. transformer, the 6K7, V_3, the second 100 kc/sec. transformer, and at the back, the 6H6, V_4. These components are in a row along the outside edge of the chassis. There is thus room for a second row between these and the C.R.T. box. This row is not full, of course, but right beside T_1 we have V_2, the reactance tube, and beside V_1 there is the small can housing T_2, the oscillator coil. Then, directly behind T_2, and beside T_3, is the sweep control, R_{22}. A midget knob on the shaft of this potentiometer can just be seen in the photograph. Finally, at the back of the row, next to the 6H6, is V_7, the voltage regulator tube.

On the other side of the C.R.T. box are the power supply components, the two rectifiers, and the time-base valves, V_5 and V_6. These are side-by-side in front of the rectifier valves, and a little more than half-way down the chassis from the front. The power transformer is mounted approximately an inch from the front panel, leaving just enough room for a potentiometer to be mounted on the panel behind it. The rectifiers are as close as possible to the transformer, so as to make the power supply wiring as compact as possible. The 6N7, V_8 and V_9, is to be seen at the back of the chassis, with the potentiometer R_{24} beside it. Note how the pre-set potentiometers have been left with their shafts intact, and knobs fitted. This makes final adjustment much easier, and facilitates readjustment, which may have to be done after long periods of use, or after changing some of the valves.

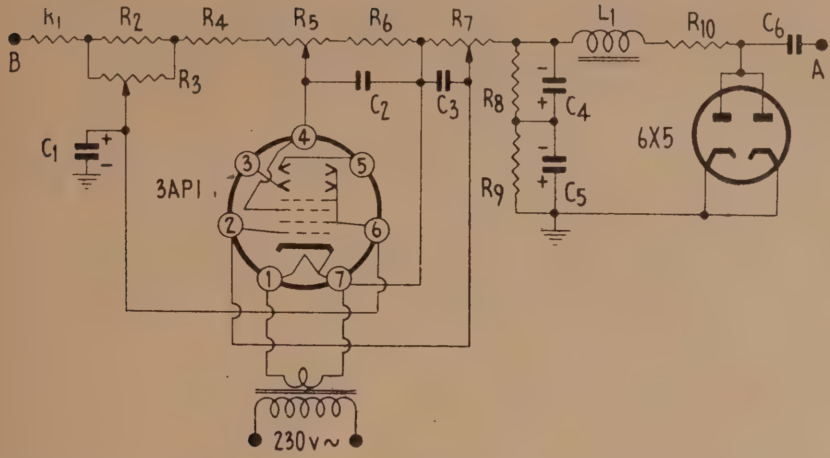
The controls brought out to the front panel are the brilliance and focus controls for the C.R.T. and the R.F. gain control. The latter is in the centre of the chassis front, while the other two are mounted on the front panel, above the chassis, and on a level with the centre of the cathode ray tube. At the left of the chassis front is the input connector, close to the input transformer T_1, and on the right, balancing this in appearance, is the on/off switch. The lay-out is so simple and straightforward that we have conserved space by not printing a diagram of the chassis. As long as the R.F. portion is laid out in a simple and logical way, as we have described, there is no reason why any lay-out for the rest of the circuit should not be used.

However, should readers wish us to print a diagram of the chassis used in the original, we will be pleased to do so.

Power Supply Arrangements

In the first instalment of the article, we did not show the power supply for the unit. This is quite conventional, and is shown in Fig. 2. This diagram refers to the voltages labelled on the main circuit diagram of Fig. 1, where the two D.C. voltages of 320 and 250 are shown as terminals. The point A on the two diagrams are connected together, showing where the input voltage for V_5 is taken from, namely, from one side of the H.T. secondary of the power transformer. Fig. 1 and Fig. 2 together show the complete unit for use with an external cathode ray tube.

If the C.R.T. is to be built in, the extra power supply circuit of Fig. 3 is needed, and this, too, is built into the unit itself. It will be noticed that building in its own cathode ray tube does not mean the provision of a second high-voltage transformer. Instead, a dodge is used, which enables the tube to get an effective supply voltage of some 580 volts. This consists in using a 6X5 as a shunt



R_1, 250k.
R_2, R_8, R_9, 1 meg.
R_3, 1 meg. pot.
R_4, 50k.
R_5, 500k. pot.
R_6, 200k.
R_7, 100k.
R_{10}, 50k.
C_1, 8 μf. 450v. Electro.
C_2, C_3, 0.05 μf. 600v.
C_4, C_5, 8 μf. 450v. electro.
L_1, 30 ma. smoothing choke.

rectifier, fed through a condenser from the point A on the main power supply diagram. A smoothing circuit is used, consisting of a choke-input single section, and this provides a voltage of approximately 400, negative with respect to earth. Now, instead of connecting the final anode of the C.R.T. to chassis, in the usual way, it is returned to a point on the positive power supply, approximately 190 volts positive with respect to earth. By this means, the C.R.T. has across it an effective H.T. voltage of 400 plus 190, or 590 volts, which is ample for good definition from the 3AP1. At first sight, it might appear that there is no shift control on either axis, but this is not so. A simplified shift control is used, whereby a single control is able to centre the picture nearly enough for all practical purposes. The deflection plates are connected directly to the plates of V_8 and V_9, the amplifier tubes, so that their mean potential is fixed by the potential which appears at the plates of these tubes. In order to prevent de-focussing of the spot, it is therefore necessary to return the final anode of the tube to a similar potential. This is done by means of the pre-set potentiometer R_2, which enables the final anode potential to be varied until the right voltage is arrived at. This control also acts as a shift control, on both deflection axes at once, so that when R_2 is manipulated, the spot will be seen to shift, not vertically or horizontally, but diagonally. Now, in the adaptor, the best place for the trace is right across the centre of the tube, since here it is longest, and therefore gives best value for money in terms of trace length per pound of tube cost. Also, half the height of the tube is ample for the signal deflections so that there is no real need for shift controls which can shift the spot to any part of the screen. Most tubes do not put their un-deflected spot exactly in the centre of the tube, however, so that shift controls might again seem essential. But the combined horizontal and vertical shift, or rather diagonal shift, is perfectly satisfactory for compensating for small departures of the tube from exact centring.

(To be concluded.)

OUR GOSSIP COLUMN

Visit of British Thomson-Houston Export Chief

On a short visit to the Dominion, Mr. E. V. Small, Director and Manager of the British Thomson-Houston Export Co., Ltd., was guest of honour at a dinner party given by the Directors and Management of the National Electrical and Engineering Co., Ltd., at the Royal Oak Hotel on Tuesday, November 30th.

The occasion had a double significance in that it also celebrated the appointment of a new General Manager for "National Electric," Mr. C. E. Fuller, M.M., B.E., M.N.Z.I.E., who succeeds the late Mr. Frank S. Taylor. Mr. Fuller had held the position of Chief Engineer to the Company since 1939.

In a speech welcoming Mr. Small to New Zealand, Chairman of Directors Sir Charles Norwood spoke of the long and happy association between the British Thomson-Houston Co. and "National Electric," who have held the sole New Zealand agency for B.T.H. products since 1906. The Chairman also took the opportunity of congratulating Mr. Fuller and wishing him all success in his new appointment.

Mr. Small, replying to Sir Charles Norwood, thanked him for his kind greetings and said that the visit would prove most valuable in even further cementing the good relations that had always existed between the two Companies, and that he would leave New Zealand happy to know that the B.T.H. agency was in such capable hands. He was very pleased to hear of Mr. Fuller's appointment and wished him every success.

Also present were Messrs. R. J. Hudson and A. G. Stephens (Directors), Mr. Nelson Jones (Managing Director), and executive members of "Neeco" staff.

* * *

B.T.H. Overseas Association Reunion

Together for the first time since 1938, twelve members of the B.T.H. Overseas Association were guests of Mr. E. V. Small for a luncheon party at Wellington's Royal Oak Hotel on Monday, November 29th.

Mr. E. V. Small, Director and Manager of the British Thomson-Houston Export Co., Ltd., England, is at present on a short visit to New Zealand, following a similar tour of Australia.

After luncheon, Mr. Small addressed the party informally, expressing his pleasure at being able to meet ex-members of the B.T.H. Co. and as President of the Association offered warmest greetings from Home members.

Mr. Small is an old-established member of the Association, having spent 25 years with A.E.I.'s Indian organization.

In addition to Mr. Small, those present included: Messrs. R. J. Campbell, G. Durham, F. C. Fenwick, C. E. Fuller, F. K. Garry, H. C. Hitchcock, J. K. Horn, Nelson Jones, J. H. Lee, S. C. MacDiarmid, N. H. Matthews, E. W. I. Meyer, and J. McC. Stewart.

A similar gathering was organized for Auckland members, who were entertained by Mr. Small at a cocktail party held there at the Grand Hotel on Monday, November 15th. It was attended by Messrs. E. Hitchcock, E. Hutchison, Nelson Jones, K. L. Lee-Richards, R. Maxted, T. G. Proctor, W. Welch, and C. Wilson.

* * *

A recent visitor to Wellington has been Mr. H. M. A. Beach, newly-appointed Sales Manager to Westonhouse Radio Ltd., Auckland. As a fairly recent arrival from England, Mr. Beach considers that conditions here are extremely agreeable after the long period of austerity in the Old Country. With his wide experience in the electrical field in England, Mr. Beach is assured of a warm welcome to the New Zealand Radio fraternity.

* * *

Recent visitors to our office in Wellington have included Mr. Jim Eckford, of S.O.S. Radio Ltd., Auckland, and Mr. E. B. Borham, of Borham's Radio Ltd., Palmerston North.

* * *

Tony Bates, of T.R.E., returned to England early in January after a sojourn of two years in this country where he was employed on the Canterbury project. We are assured, however, that he will forever remember New Zealand as he is now the proud father of a bonnie daughter born shortly before his departure.

* * *

Mr. E. L. Brisbin, Chairman of the Board of Directors of Eveready (Australia) Pty. Ltd., of which National Carbon Pty. Ltd. is an affiliate company, spent a well-earned holiday in New Zealand during November last. Mr. Brisbin, who was accompanied by Mrs. Brisbin, was particularly impressed with the scenic beauty of the South Island.

* * *

New General Manager for National Electrical and Engineering Co. Ltd.

The National Electrical and Engineering Co., Ltd., has announced recently the appointment of Mr. C. E. Fuller, M.M., B.E., M.N.Z.I.E., to the position of General Manager as successor to the late Mr. Frank S. Taylor. After four and a half years' active service with the Australian Imperial Forces in World War I, Mr. Fuller graduated from Sydney University, first spending two years in the service of the Electricity Department of the Sydney Municipal Council, and from 1924–1932 being employed by the Australian Branch of Messrs. Ferguson, Pailin Ltd., where he rose to the position of Assistant General Manager, and came to New Zealand in 1932 as Factory Representative of that same firm.

In 1935 he joined the National Electrical and Engineering Co., Ltd., as Sales Engineer, being appointed to the position of Chief Engineer in 1939. Representing this company, Mr. Fuller visited Canada, the United States, and Great Britain during 1946–7, where he discussed matters affecting its interests with officials of the Canadian General Electric Co., Ltd., the General Electric Co. Inc. (U.S.A.), the British Thomson-Houston Co., Ltd., and other of the National Electric Company's overseas principals.

* * *

Spotlights on the Radio Manufacturers' Association Conference at Rotorua

One of the highlights of the recent Radio Manufacturers' Association Conference at Rotorua was the finding of the "Fluorescent Kidney" in the early hours of the morning. This delectable morsel, if not eaten for breakfast the following morning, would prove a suitable substitute for the Crown Jewels if required.

Eight members took part in the golf match (handicap), but found the time allowed insufficient to complete the full course. After weighty discussion, however, Bill Meighan was declared the winner. Congratulations, Bill!

Evening entertainments in Rotorua were arranged by the Auckland branch of the R.M.A. The Maori concert held on the Wednesday evening proved a great success, whilst the dance arranged for Thursday was also thoroughly enjoyed, those not actively taking part finding an opportunity for friendly discussion, etc.

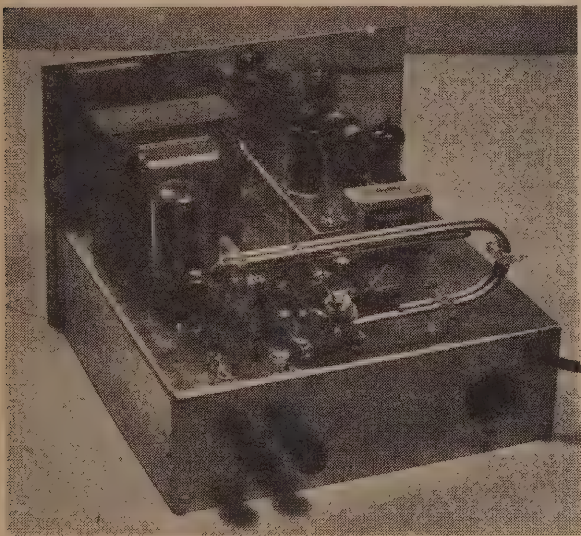
The PHILIPS Experimenter

An Advertisement of Philips Electrical Industries of New Zealand.

No. 15: (a) A RECEIVER FOR THE 166-170 mc/sec. AMATEUR BAND (conclusion); (b) A COMPANION TRANSMITTER FOR THE ABOVE RECEIVER.

Setting up the Complete Receiver

When construction has been completed, the receiver has to be aligned so that the super-regenerative detecor works exactly on 60 mc/sec., and the local oscillator covers 226-230 mc/sec. when tuned with the bandspread condenser. The first step is to adjust the I.F. circuits, and this is very easily done as long as some kind of signal is available on the correct frequency. If the signal generator does not reach far enough, the second harmonic of 30 mc/sec. can be used. The procedure is simply to couple the signal generator or other oscillator very loosely first to the second detector tuned circuit, then after tuning in with the trimmer, the oscillator is coupled to the mixer cathode circuit, and with the EAF91 removed, this circuit is peaked for maximum response.



Rear view of the transmitter. The construction of the folded line can be clearly seen.

In order to set up the local oscillator, Lecher lines are needed. They are coupled as loosely as possible to the oscillator line, and resonance is indicated by means of a 0-1 ma. meter connected in the oscillator grid return. With the bandspread condenser at full capacity, the band-setting condenser is adjusted so that the frequency measured by the lines is exactly 226 mc/sec. It will be found that the correct setting is with the moving plates out of mesh altogether, and about 1/16 in. from the fixed plates. The adjustment is quite critical, but once found will hold perfect y as long as the construction is quite rigid. The next step is to move the bandspread condenser to minimum capacity and check the frequency of the oscillator again. If it is lower than 230 mc/sec., it will be necessary to reduce the spacing in the bandspread condenser by using a slightly larger distance piece between the two rotor plates. The oscillator adjustment should be made with the input tuning condensers both at maximum capacity, ensuring that the input line is tuned much lower in frequency than the final oscillator frequency.

Final adjustment is that of the input line's band-setting condenser. To do this, a signal at 168 mc/sec. is picked up from a nearby transmitter or a rough oscillator constructed for the purpose, and without re-setting the oscillator condenser, the signal is peaked by tuning the band-setting condenser, the bandspread condenser having previously been set at half-scale.

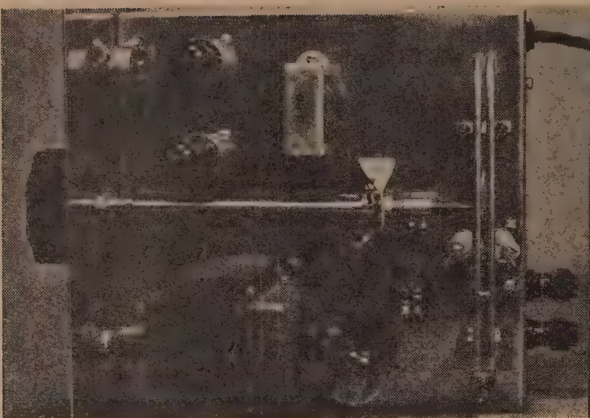
Next month's experimenter will describe a companion transmitter for this receiver. It is constructed on an identical chassis, and uses and ECC91 as a push-pull line-controlled modulated oscillator modulated by an EL41. Power supply is included and switching arrangements enable the receiver to draw its supply from the transmitter so that the two act as a single transmitter-receiver.

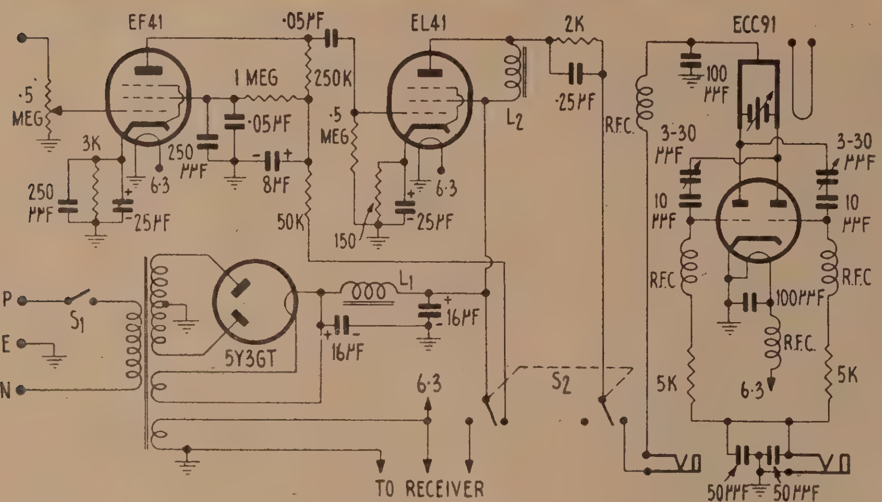
The Transmitter

This month's feature is a transmitter, intended to work in conjunction with the receiver that has just been described. It contains its own power supply, and arrangements have been made to use this for the receiver also, by means of a stand-by switch which is mounted on the transmitter panel. The transmitter is complete with modulator and speech amplifier, which has sufficient gain for a Philips high-impedance dynamic microphone to be used. The basis of the transmitter is the oscillator circuit, for the ECC91, which was described some time ago in "Philips Experimenter No. 12," so that this part of the transmitter will need little comment, except from the constructional point of view. The speech amplifier is an EF41, and the modulator an EL41, which is capable of supplying more than enough audio power for fully modulating the oscillator.

The stand-by switch, S_2, not only switches off the H.T. supply to the oscillator, but also changes it from the speech amplifier to the receiver, leaving the EL41 going at all times. The idea here is to allow the modulator to act as a bleeder across the power supply, so that the H.T.voltage does not rise too high. Without a bleed of some sort, this would occur, because the current drain of the receiver is much less than that of the transmitter.

The modulator is of the Heising variety, and works very nicely. This is probably due to the fact that the 40 ma. drawn by the oscillator under load gives it an impedance of 6250 ohms when viewed by the modulator. This figure is quite close enough to the official 7000 ohms load recommended for the EL41, especially in view of the fact that it is not called upon to deliver more than 2.5 to 3 watts. Since an oscillator or modulated amplifier presents a reasonably constant load to the modulator, it is unnecessary in an application like this one to apply feedback to the modulator in order to minimize distortion. The modulation characteristics of the transmitter as a whole are excellent, and a virtually perfect trape-





zoidal modulation pattern was obtained on an oscilloscope at all modulation levels. This does not mean that 100 per cent. modulation is advisable with a transmitter like this, even when the receiver is comparatively inselective, because, although the oscillator is well constructed and uses transmission-line tuning, there is inevitably a considerable degree of frequency modulation taking place, particularly at high modulation levels. It is good practice, therefore, to limit the modulation to about 70 per cent.

Construction of the Transmitter

The form taken by the transmitter is pretty well shown by the photographs. The chassis is the same size as the receiver, and so is the front panel. On the latter can be seen the main tuning dial, on the left of which is the microphone gain control, and on the right the send/receive switch. Below, from left to right, are the microphone input connector, the oscillator plate and grid current jacks, and the power supply on/off switch.

The construction of the oscillator section can be seen from the rear view, in conjunction with the one looking down from above. In the latter, the power supply transformer and rectifier can be seen, above the tuning shaft, while below it are the speech-amplifier and modulator valves and the modulation choke. The valve nearest the gain control potentiometer is the EF41.

The ECC91 is mounted upside-down, and cannot be seen in the photograph. Its socket is hidden, too, by the chokes and the grid condensers, but its position can be gauged by the fact that the Philips trimmers are mounted directly on the plate pins of the socket.

Tuning is carried out both by means of an adjustable shorting bar on the oscillator lines, this being used for coarse adjustment in finding the band, while fine tuning, with the bandspread over about 100° of rotation, is accomplished with the three-plate home-made butterfly condenser, similar to the one used for oscillator tuning in the receiver. The shorting bar can be seen in both photographs, and the butterfly condenser is clearly visible in the back view.

The lines have been bent, simply to enable them to be got into the available space. Before bending, they are cut to a length of 10½ in. and are then bent round in a circle of 1¾ in. diameter, so that the shorter straight piece is 2¼ in. long. They are mounted on insulating brackets made from ⅛ in. thick perspex, which are fixed to the chassis with self-tapping screws. The spacing between the lines is ¼ in. between centres, leaving ⅛ in. between the inside edges, since the material is ⅛ in. copper or brass rod. The tail piece of perspex measures 2½ in. x 1 in., and is used to support three solder lugs, two for the output coupling hairpin and one for the H.T. end of the R.F. choke, which can be seen in the photograph, attached directly to the line, after the latter has projected ⅜ in. through the perspex. The fixed plates of the butterfly condenser are 1 in. x ½ in., and are soldered to the lines so as to leave a space of ⅛ in. between them. The rotor, which is supported on a small piece of insulating ¼ in. rod, is semi-circular, and is ⅝ in. in radius. The shaft is attached ⅜ in. from one end of the plate, and slots are cut in the stators to allow the shaft to pass through them, at such a level that the rotor's straight edge is level with the top edges of the stators, when fully unmeshed.

THE RADIO MANUFACTURERS' FEDERATION CONFERENCE

Members of the New Zealand Radio Manufacturers' Federation gathered in Conference at Rotorua on 17th and 18th November, 1948, take time off for a group photograph outside the imposing Rotorua Borough Council Chambers. Seated (left to right): W. J. Meighan, W. I. Cunninghame, D. T. Clifton Lewis, W. L. Shiel, Wm. J. Blackwell (President), P. C. Collier (Vice-President), R. Slade, T. J. F. Spencer. Back row: David J. Reid, S. D. Mandeno, T. R. Gobby, G. A. Wooller, A. Clive Johns, Chas. H. Hart, A. G. McCarthy, N. Swann, B. Bookman, D. A. Clark (Group Secretary).

Meeting for the first time away from one of the main centres, the New Zealand Radio Manufacturers' Federation held a most successful Conference on 17th and 18th November, 1948. Addressing the opening session of the Conference, Mr. W. J. Blackwell, President, of Auckland, dealt with numerous matters of vital importance to all units of the industry, including the increase of New Zealand's normal annual replacement rate of radio receivers, patents and royalty matters, and code of standard trade practice.

One and a half days of discussions were held, a full report of which will be included in the next issue of this journal.

The "Junior" Communications Receiver

(Continued from page 5.)

not among their number. Tests carried out in a scientific manner have shown that a receiver with a triode mixer can be made to have a better noise factor than one with an R.F. stage which does not use a high-g_m low-noise pentode. At high and medium frequencies, in which this set is interested, it has been shown that it is very doubtful whether a pentode even of the kind mentioned gives a set with a well-designed triode mixer circuit any improvement at all in signal-to-noise ratio. Not that this is the only factor to be considered, for it is not, since other considerations, such as image response, have their share in saying whether or not an R.F. stage should be used.

Because the following characteristics are desirable in any communications receiver, the present design attempts to achieve them, and succeeds to gratifying extent.

(1) Good signal-to-noise ratio.
(2) Good image rejection.
(3) High sensitivity.
(4) High selectivity.

How the set goes about realizing these things can best be described while outlining the valve line-up.

Valve Line-up and General Scheme of the Set

Points (2), (3), and (4) above are all taken care of by the initial decision to use a double-superheterodyne circuit. That is to say, two mixers and two intermediate frequencies are used. The first valve in the set is a 6J6 double triode, which is used as a triode mixer and untuned buffer. As mentioned above, the triode mixer gives the set its good performance as far as signal-to-noise ratio is concerned. The second section of the 6J6 acts as a cathode follower to the oscillator frequency, which is injected directly on to its control grid. The first intermediate frequency is 1.6 mc/sec., which helps in two ways. First, it enables the image rejection to be quite good, even though there is no R.F. stage. Secondly, and this is quite important where the aerial tuning is not ganged with the oscillator, it helps to prevent "pulling" of the oscillator frequency by the control of the mixer input tuning. The R.F. oscillator uses a 6C5, or 6J5, either of which could be used without alteration of circuit values. On the first I.F. of 1.6 mc/sec. there is a stage of amplification employing a 6BA6, which is a high-g_m R.F. pentode, with the result that the gain of this stage is quite high—much higher, in fact, than would be the case with a 6K7 or 6SK7 in this position. This high gain is a good thing, since the next valve in the circuit is an ECH35, used as the second oscillator and mixer. This valve is excellent for this position in the set, on account of its extreme stability under A.V.C. conditions, but it is an advantage to have plenty of gain ahead of it so that its inherent noise will not show up. As a matter of fact, the ECH35 is one of the best of the multi-grid mixer tubes from the noise point of view, but even so it cannot compare with a triode in this respect by a very long way. By means of having the high-gain 6BA6 stage ahead of it, however, its only disadvantage is virtually eliminated. After the ECH35 comes an EF39, as an I.F. amplifier on 100 kc/sec., this being the frequency to which the second mixer heterodynes the 1.6 mc/sec. signal from the first I.F. stage.

The advantage of going to a low second I.F. is that by so doing one automatically gains a great deal of selectivity. This comes about as follows. There is a simple formula which relates the selectivity of a tuned circuit to the other important factors, its frequency, and its Q. It is:— $\Delta f = f/Q$

where Δf is the bandwidth between the points on the selectivity curve of the circuit where the response is 0.707 of the peak value, f is the frequency to which the circuit is tuned, and Q is the numerical value of the Q of the tuned circuit.

This simple relation shows that if we assume that all coils we wind have the same Q, then the bandwidth depends only on the signal frequency. If this is halved, so is the bandwidth, or, in other words, the selectivity has been doubled. Now, a figure of 100 is a commonly realized value for the Q of the windings of ordinary 465 kc/sec. I.F. transformers, and there is no reason to suspect that if we have a 100 kc/sec. I.F. transformer made, it will have a smaller Q than this. Suppose, then, that this is the Q of our 100 kc/sec. winding. Applying the formula, we find that the bandwidth is

$$f = \frac{100{,}000}{100} = 1000 \text{ c/sec.}$$

This shows that, roughly speaking, two double-wound transformers would have a response which is 12 db. down at 1 kc/sec. from resonance. Now this is quite high selectivity, and is obtained as easily as one can instal a simple mixer and 100 kc/sec. I.F. amplifier. Normal communications receivers using a higher I.F. in the region of 465 kc/sec. would have to have a number of stages in order to achieve anything like the same selectivity without the use as well of a crystal filter. The main disadvantage of the 100 kc/sec. channel is that, unlike a crystal filter, its selectivity cannot easily be varied to suit reception conditions.

(To be continued.)

NEW PRODUCTS

THE "BRS" (DUAL-SPEED) DISC-RECORDING AND PLAYBACK UNIT—MODEL R-12

Manufactured by Byer Industries Pty., Ltd., the above unit will shortly be released by the Swan Electric Co., Ltd., P.O. Box 90, Wellington.

This recorder-playback unit has been designed and manufactured for use by professional and amateur recordists who require a machine capable of recording at 78 r.p.m. on 12-inch, or smaller, discs, records for immediate playback purposes. Simplicity of operation, robust construction, faithful recording and reproduction, and pleasing appearance were the essentials borne in mind when planning and producing this unit. Recordings may be made on acetate base discs when the unit is connected in accordance with the instructions to any amplifier or high-grade radio having pick-up connection facilities.

As a recorder, the unit may be put to any one of many uses, amongst which are included the following:—

In the home.—Record your children, your favourite programme, musical items at parties, commentary for films, surprise recording of friends.

For artists.—Recordings of voice or instrument for comparison and self-analysis.

For the businessman.—Recordings of speeches, company meetings, sales conventions, etc.

As a playback unit, this machine provides a constant speed turntable and a pick-up unit suitable for playing all lateral recordings up to 12 inch with remarkable fidelity.

The frame and turntable are manufactured from sand-cast aluminium alloy, machined on all necessary surfaces and finished in baked enamel. Traversing mechanism is by worm and quadrant, is fully enclosed and impossible to become out of adjustment except through misuse. Engagement of the traversing gear is effected through a simple lever and lock giving "cut" and "play" positions.

The cutting arm is accurately counterbalanced by an adjustable spring to give the correct weight at the needle point. The cutting head is of the moving iron type, giving a good response both for cutting and playback up to 6,000 cycles a second, the one head performing both functions.

The frame is drilled for mounting, and in setting up it is essential that it be screwed firmly to an even, level surface.

SPECIFICATIONS

Size of base.—14¾ in. long by 13¾ in. wide.
Height from bottom of plate to top of cutter arm.—2 in.
Depth from bottom of plate to lowest point of motor.—5 in.
Turntable diameter.—12 in.
Turntable speed.—78 r.p.m. and 33⅓ r.p.m.
Maximum diameter of disc which can be recorded or played.—12 in.
Maximum cutting circle diameter.—11½ in.
Minimum cutting circle diameter.—3½ in.
Motor specification.—240 volt, 50 cycle, A.C., 1/60 h.p., 1,500 r.p.m., synchronous, 40-degree Centigrade temperature rise, current consumed 0.16 amp.
Cutter head impedance.—4,000 ohms at 1,000 cycles.
Groove spacing.—112 lines an inch.
Land to groove ratio.—40 to 60.

HIGH-FREQUENCY INDUCTANCES

(Continued from page 18.)

With P.V.C. coils in a standard receiver using 6SK7, 6K8 tubes, the image frequency has been checked at 46 db. below the fundamental.

THE OSCILLATOR CIRCUIT

The rising Q factor of a P.V.C. oscillator coil presents some problems. On the basis of the standard converter circuit of Fig. 2, if the coil has sufficient coupling to give adequate oscillator grid current at the low frequency end of the tuning range, the coupling may be sufficient to cause parasitic oscillation at the high-frequency end of the scale. Fortunately, the problem is only a minor one, and can be overcome by the addition of a grid suppressor shown as R in Fig. 3.

CONCLUSION

The writer feels that some apology is necessary for the lack of more complete information on moisture absorption and temperature co-efficient. However, readers will realize that the P.V.C. coils represent an entirely new departure in coil design, and full data on their characteristics will take a long time to compile. Tests completed at this stage indicate that the P.V.C. coils are superior in almost every respect to the standard coils available on the market, and it is to be hoped that from time to time further information will appear in the pages of this magazine.

ELECTRONIC MUSICAL INSTRUMENTS

(Continued from page 33.)

longed dwell on the make. The writer has used it successfully for even such low frequencies as 1 cs/sec. to 20 cs/sec. for the successful operation of magnetic counters.

In our next article we will consider some further oscillator systems and methods of harmonic generation, and follow this with a discussion of some actual instruments that have been developed along simple lines.

PORTABLE COMPETITION

(Continued from page 8.)

Wiring the Circuit

Provided reasonable care and patience is exercised in the placing of the smaller components, no difficulty should be encountered in the wiring.

The thinnest available plastic hook-up wire should be used, and the soldering-iron should be clean and filed to a fairly sharp tip.

The first step in wiring is to earth all A — pins and the tubular shields in the centre of the sockets. It must be remembered that the DL92 output valve has a centre-tapped filament, so that pin No. 5 is earthed and Nos. 1 and 7 both connected to A + for $1\frac{1}{2}$-volt operation.

The grid lead from the DAF91 valve to the volume control is a long one, and requires shielding—indeed this shielding provides the necessary R.F. by-pass capacitance indicated by C_{14} in the circuit diagram. Incidentally, the shielding braid should be kept away from any other bare wiring by placing over it lengths of 5 mil. spaghetti at appropriate places.

The Cabinet

Figure 4 (*a*) is a perspective impression of the cabinet, looking from the rear, and shows the position of the batteries and the loop. The hinged back door has a double advantage, in that it enables the loop to be swung through 80 degrees without shifting the set, and also facilitates the changing of the relatively short-lived "A" batteries.

Figure 4 (*b*) is a front elevation of the cabinet, showing the cut-outs for the speaker and dial, and holes for the tuning and volume controls and the switch. It will be noticed that the two latter holes are large enough to admit the threaded bushes of these two components. If $\frac{1}{4}$" material is used for the cabinet, these bushes will just protrude through the panel. In the case of the switch, there should be enough thread "out front" to allow an "on/off" indicator to be attached.

All dimensions in Fig. 4 are for the inside of the cabinet.

The chassis is held in the cabinet by means of two screws (preferably self-tapping) taken through from the outside of the cabinet ends, into the centre of the horizontal $\frac{1}{4}$" flange at each end of the chassis. The two screw holes are shown in Fig. 2, and the head of one of the screws is depicted in Fig. 4 (*a*).

The back door of the cabinet can be fastened with any appropriate type of clasp. It may be found that for distant reception, the sensitivity will be increased if the set is operated with this door slightly open.

Battery Installation

A clip for the "A" batteries can be made from a piece of bakelite sheet and some thin brass. A curved piece of brass about $\frac{3}{4}$" wide is needed at either side to hold the cells in place, and a pair of spring terminals at each end, which should be paralleled and connected direct to the filament circuit, leaving the leads sufficiently long that the whole clip can be slipped out of the cabinet to change the cells. The "A" batteries should be placed in the set with the positive terminals towards the rear.

The "B" battery terminals should be mounted, properly spaced, on a strip of bakelite, again leaving the leads long enough to permit the battery to be removed from the cabinet. If the proper dome-type terminals are not available, an excellent terminal strip is provided by the original terminals of a spent Type 467 battery.

In conclusion, it is considered that this design is well within the scope of the home constructor—indeed, the prototype was built with rather less than the average facilities—and will fulfil the requirements set out at the beginning of this description—that is, the best possible performance from the smallest possible cubic capacity.